EXHIBIT 9

US006942248B2

(12) **United States Patent**
Breed et al.

(10) **Patent No.: US 6,942,248 B2**
(45) **Date of Patent: Sep. 13, 2005**

(54) **OCCUPANT RESTRAINT DEVICE CONTROL SYSTEM AND METHOD**

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(73) Assignee: **Automotive Technologies International, Inc.**, Denville, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 302 days.

(21) Appl. No.: **10/114,533**

(22) Filed: **Apr. 2, 2002**

(65) **Prior Publication Data**

US 2002/0140214 A1 Oct. 3, 2002

Related U.S. Application Data

(63) Continuation-in-part of application No. 10/058,706, filed on Jan. 28, 2002, which is a continuation-in-part of application No. 09/891,432, filed on Jun. 26, 2001, now Pat. No. 6,513,833, which is a continuation-in-part of application No. 09/838,920, filed on Apr. 20, 2001, now Pat. No. 6,778,672, which is a continuation-in-part of application No. 09/563,556, filed on May 3, 2000, now Pat. No. 6,474,683, which is a continuation-in-part of application No. 09/437,535, filed on Nov. 10, 1999, now Pat. No. 6,712,387, which is a continuation-in-part of application No. 09/047,703, filed on Mar. 25, 1998, now Pat. No. 6,039,139, which is a continuation of application No. 08/640,068, filed on Apr. 30, 1996, now Pat. No. 5,829,782, which is a continuation of application No. 08/239,978, filed on May 9, 1994, now abandoned, which is a continuation-in-part of application No. 08/040,978, filed on Mar. 31, 1993, now abandoned, which is a continuation-in-part of application No. 07/878,571, filed on May 5, 1992, now abandoned, said application No. 09/047,703, is a continuation-in-part of application No. 08/905,876, filed on Aug. 4, 1997, now Pat. No. 5,848,802, which is a continuation of application No. 08/505,036, filed on Jul. 21, 1995, now Pat. No. 5,653,462, which is a continuation of application No. 08/040,978, filed on Mar. 31, 1993, now abandoned, which is a continuation-in-part of application No. 07/878,571, filed on May 5, 1992, now abandoned, said application No. 10/058,706, is a continuation-in-part of application No. 09/639,299, filed on Aug. 15, 2000, which is a continuation-in-part of application No. 08/905,877, filed on Aug. 4, 1997, now Pat. No. 6,186,537, which is a continuation of application No. 08/505,036, said application No. 09/639,299, is a continuation-in-part of application No. 09/409,625, filed on Oct. 1, 1999, now Pat. No. 6,270,116, which is a continuation-in-part of application No. 08/905,877, said application No. 09/639,299, is a continuation-in-part of application No. 09/448,337, filed on Nov. 23, 1999, now Pat. No. 6,283,503, which is a continuation-in-part of application No. 08/905,877, said application No. 09/639,299, is a continuation-in-part of application No. 09/448,338, filed on Nov. 23, 1999, now Pat. No. 6,168,186, which is a continuation-in-part of application No. 08/905,877, said application No. 10/058,706, is a continuation-in-part of application No. 09/543,678, filed on Apr. 7, 2000, which is a continuation-in-part of application No. 09/047,704, filed on Mar. 25, 1998, now Pat. No. 6,116,638, which is a continuation-in-part of application No. 08/640,068, said application No. 09/047,704, is a continuation-in-part of application No. 08/905,876, filed on Aug. 4, 1997, now Pat. No. 5,848,802, which is a continuation-in-part of application No. 08/505,036.

(51) **Int. Cl.**[7] **B60R 21/32**
(52) **U.S. Cl.** **280/735**; 180/272; 701/45
(58) **Field of Search** 280/735, 734; 180/272; 701/45, 49

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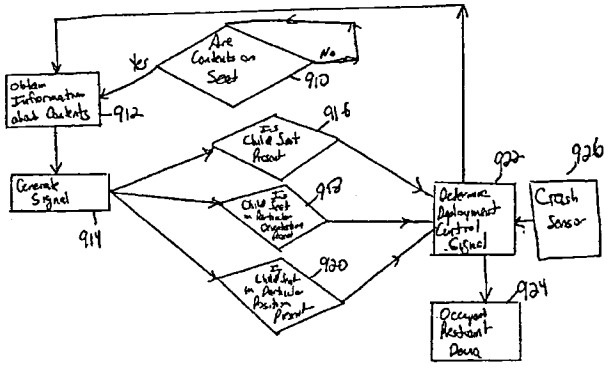

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Assistant Examiner—Toan C To
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(57) **ABSTRACT**

Control system for controlling an occupant restraint device effective for protection of an occupant of the seat including a receiving device arranged in the vehicle for obtaining information about contents of the seat and generating a signal based on any contents of the seat, a different signal being generated for different contents of the seat when such contents are present on the seat, an analysis unit such as a microprocessor coupled to the receiving device for analyzing the signal in order to determine whether the contents of the seat include a child seat, whether the contents of the seat include a child seat in a particular orientation and/or whether the contents of the seat include a child seat in a particular position, and a deployment unit coupled to the analysis unit for controlling deployment of the occupant restraint device based on the determination by the analysis unit. The analysis unit can be programmed to determine whether the contents of the seat include a child seat in a rear-facing position, in a forward-facing position, a rear-facing child seat in an improper orientation, a forward-facing child seat in an improper orientation, and the position of the child seat relative to one or more of the occupant restraint devices.

47 Claims, 34 Drawing Sheets

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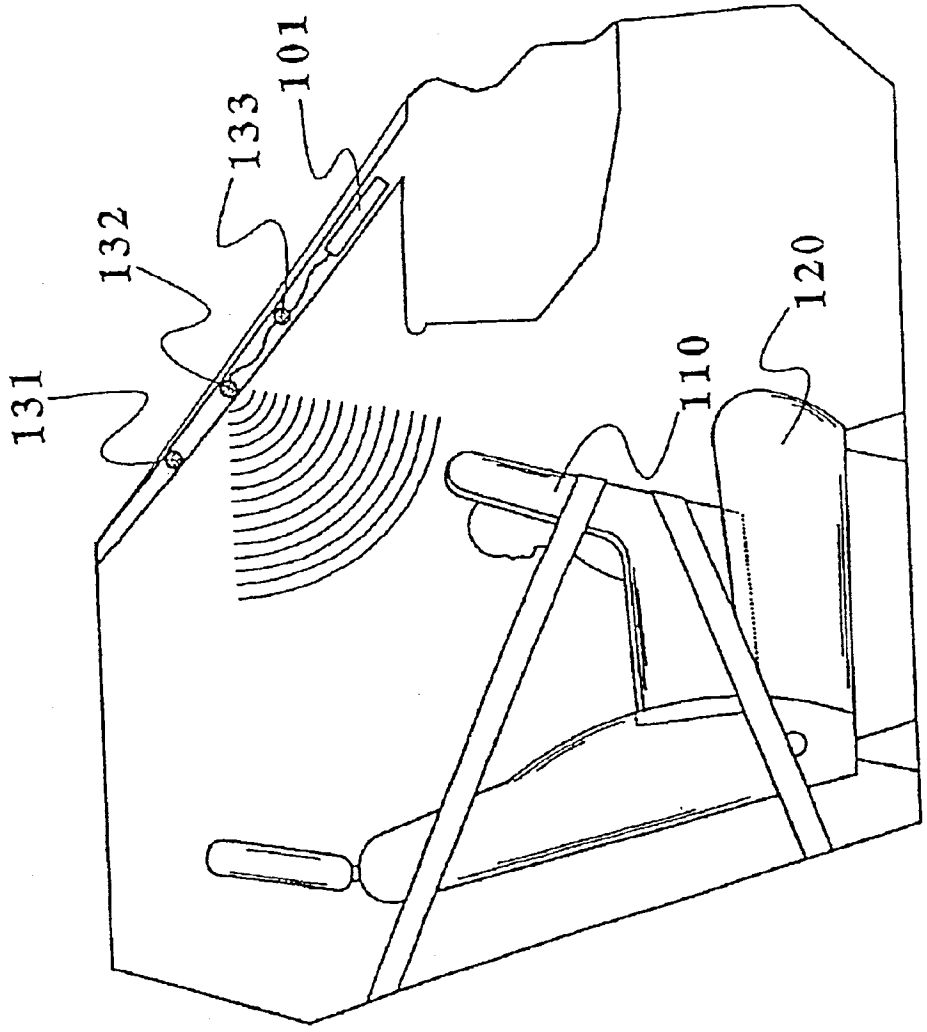

FIG. 1

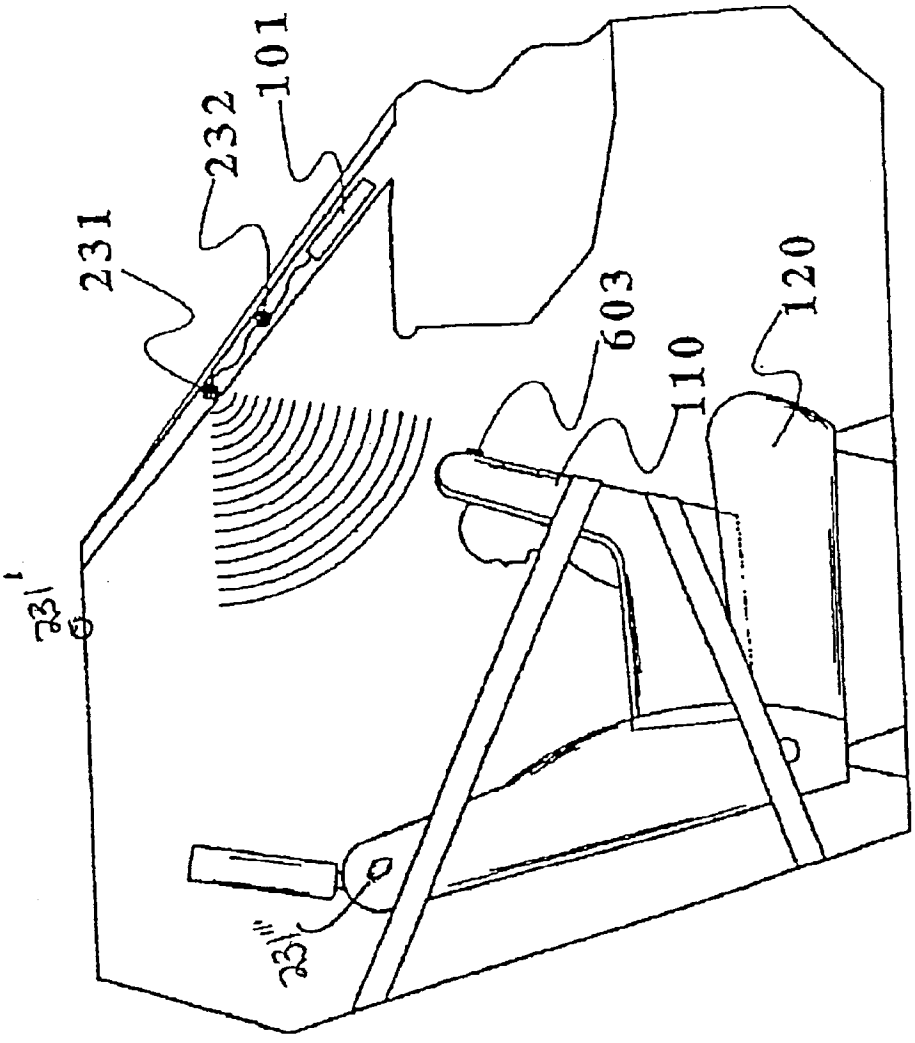

FIG. 1A

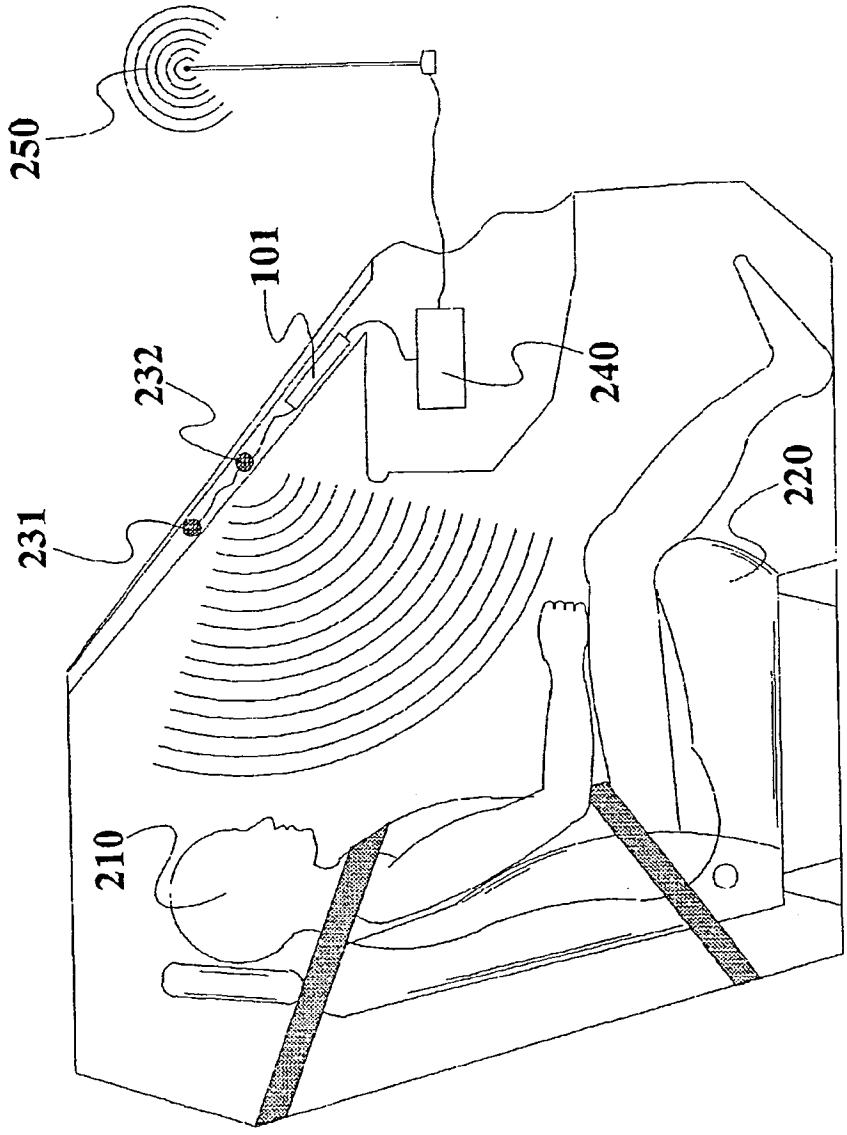

FIG. 2

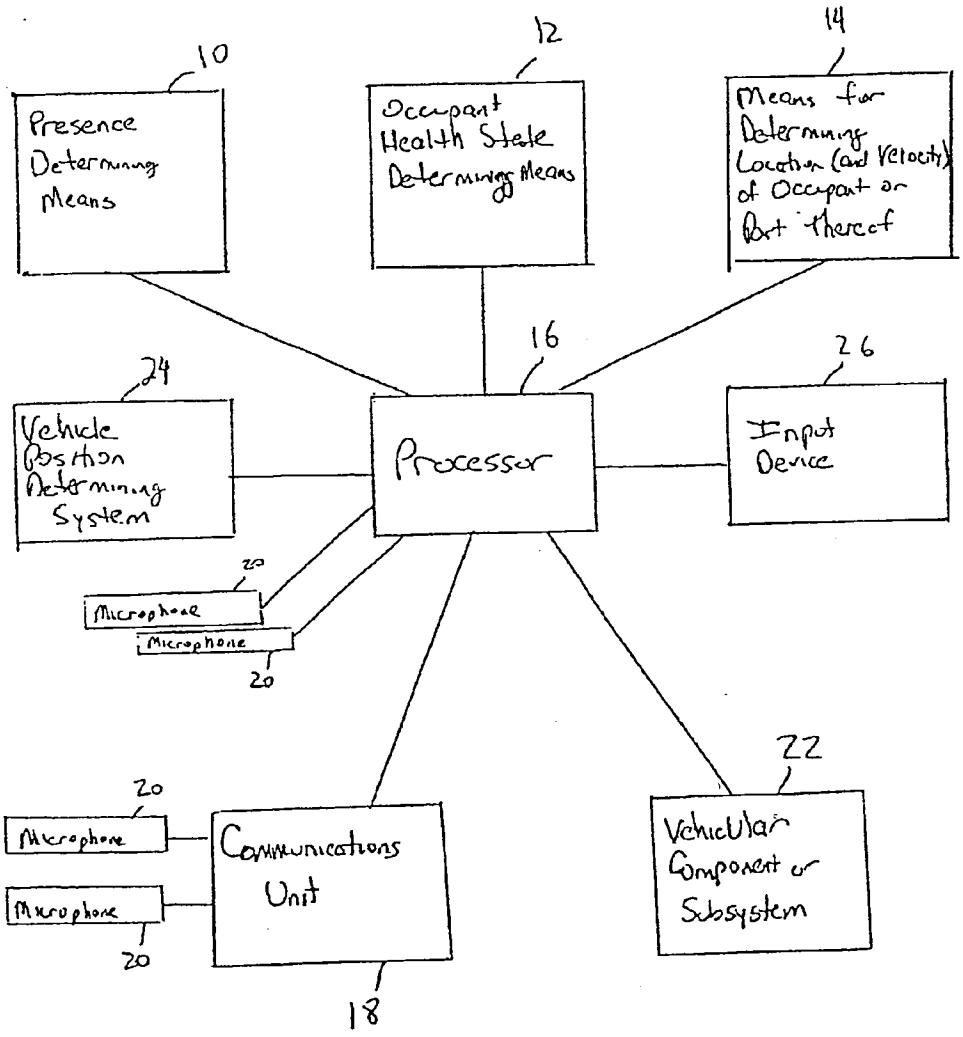
10
Presence Determining Means
12
Occupant Health State Determining Means
14
Means for Determining Location (and Velocity) of Occupant or Part Thereof
16
Processor
24
Vehicle Position Determining System
26
Input Device
20
Microphone
Microphone
20
20
Microphone
Microphone
20
Communications Unit
18
22
Vehicular Component or Subsystem

FIG. 2A

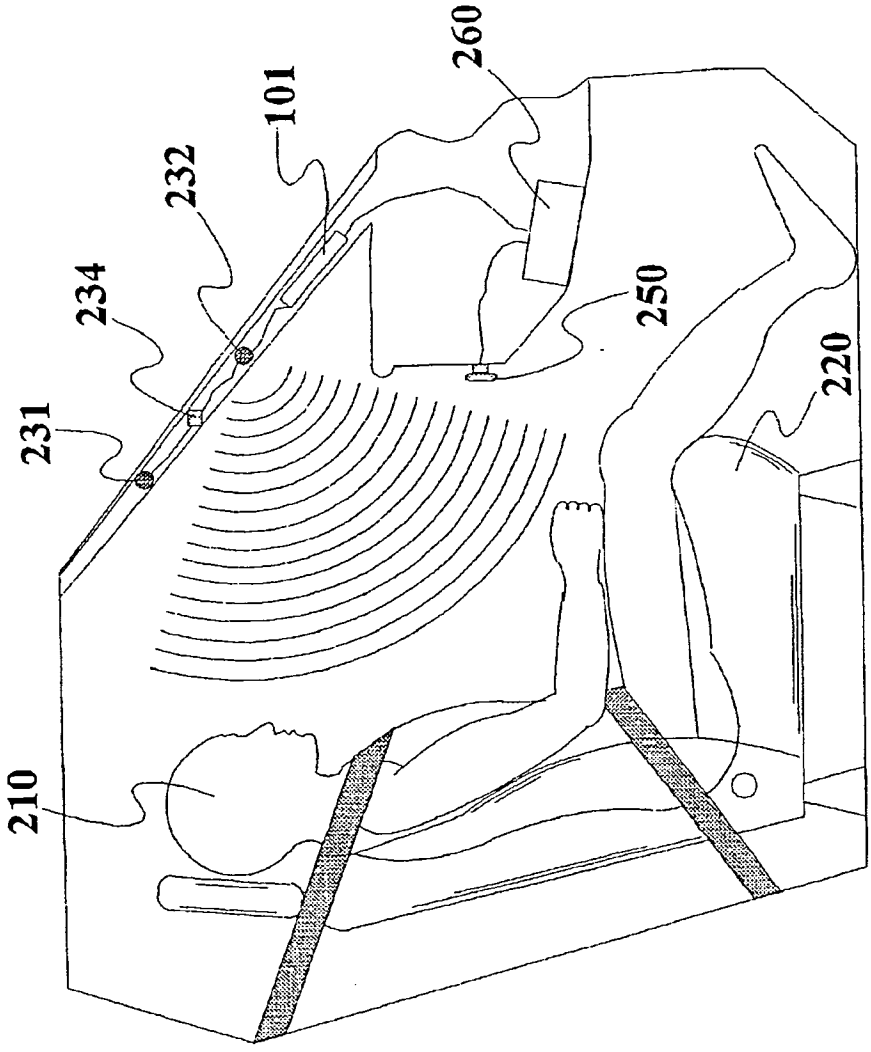

FIG. 3

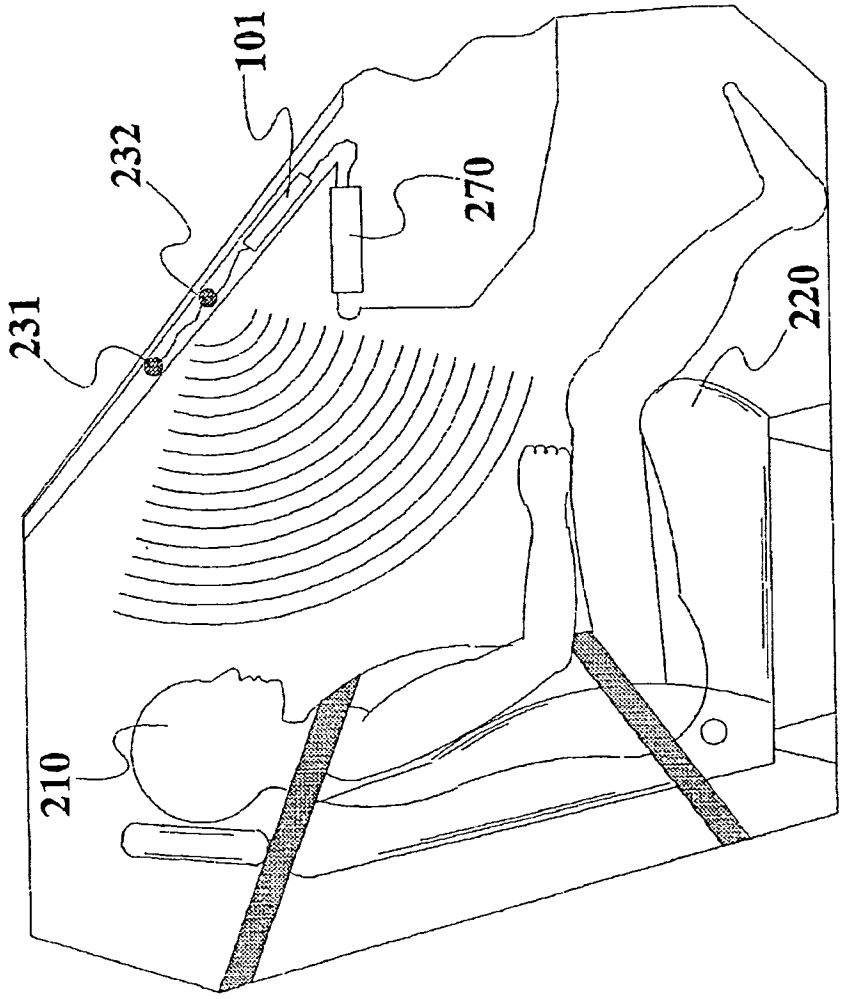

FIG. 4

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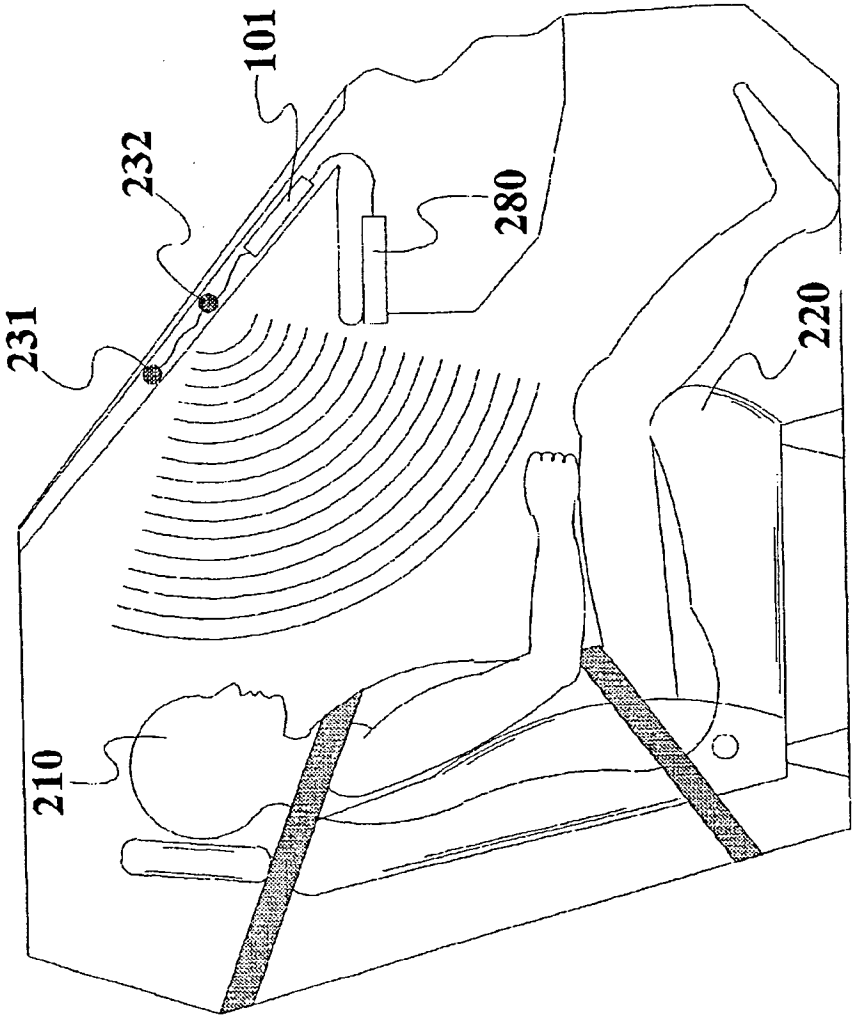

FIG. 5

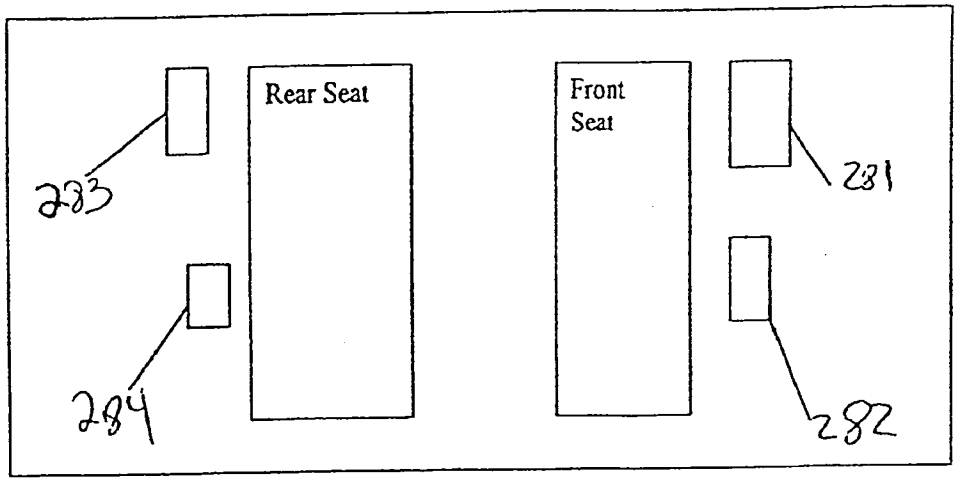

FIG. 5A

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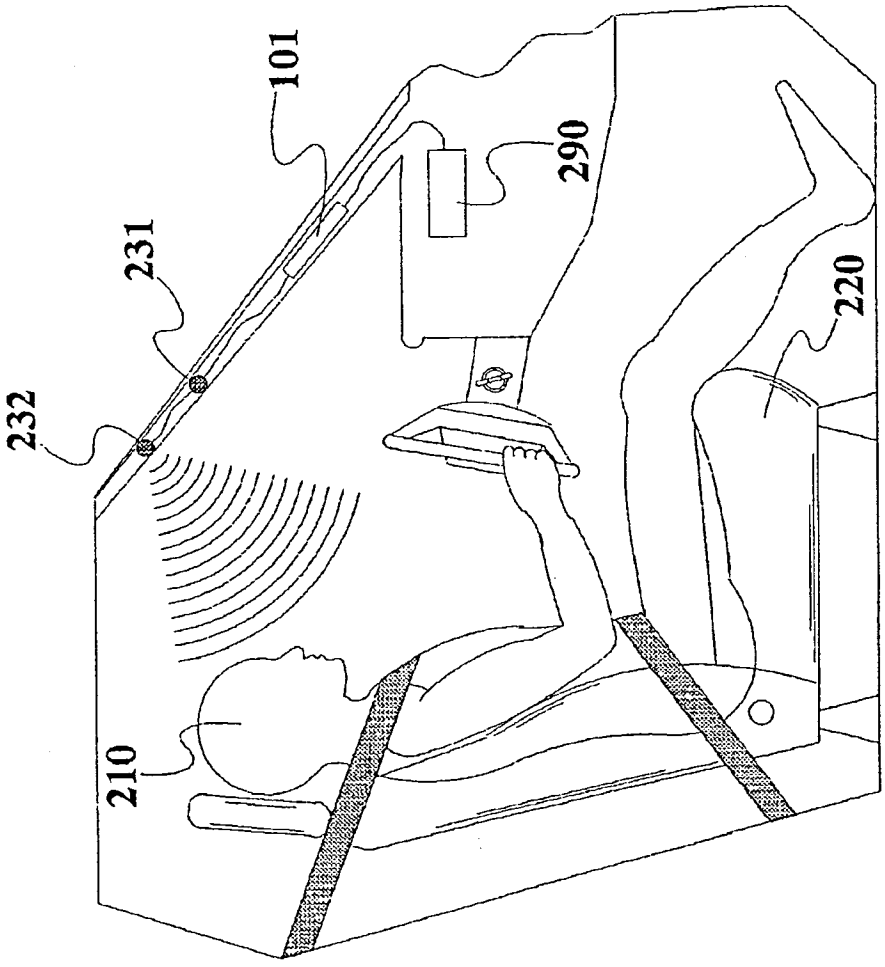

FIG. 6

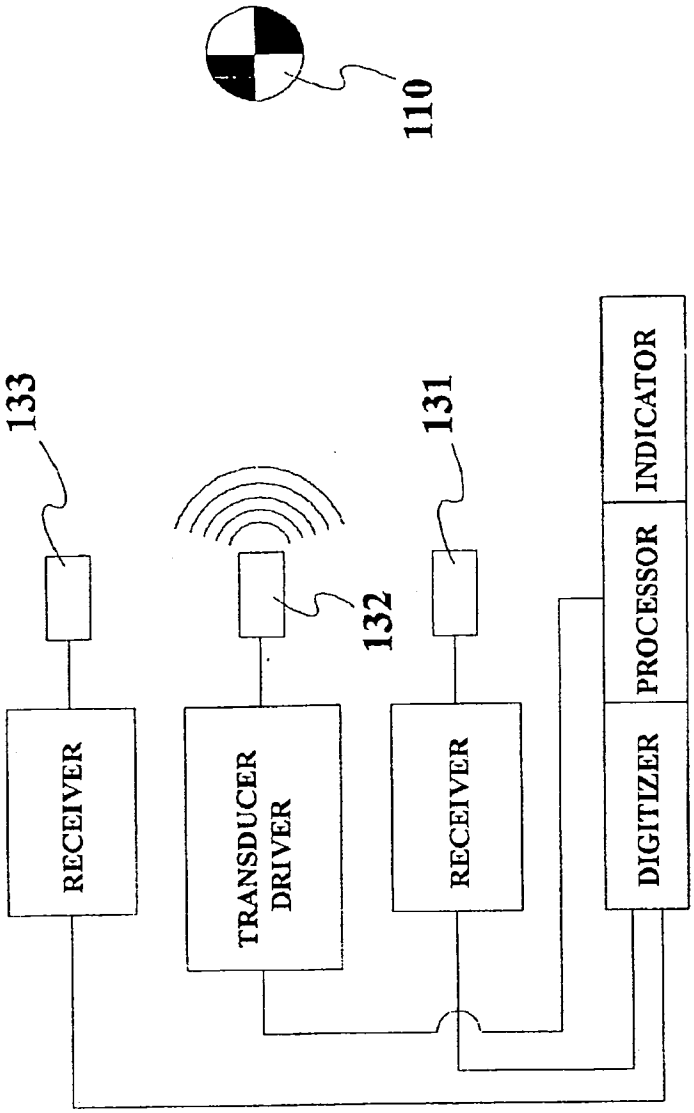
110
133
131
132
INDICATOR
PROCESSOR
DIGITIZER
RECEIVER
TRANSDUCER DRIVER
RECEIVER

FIG. 7A

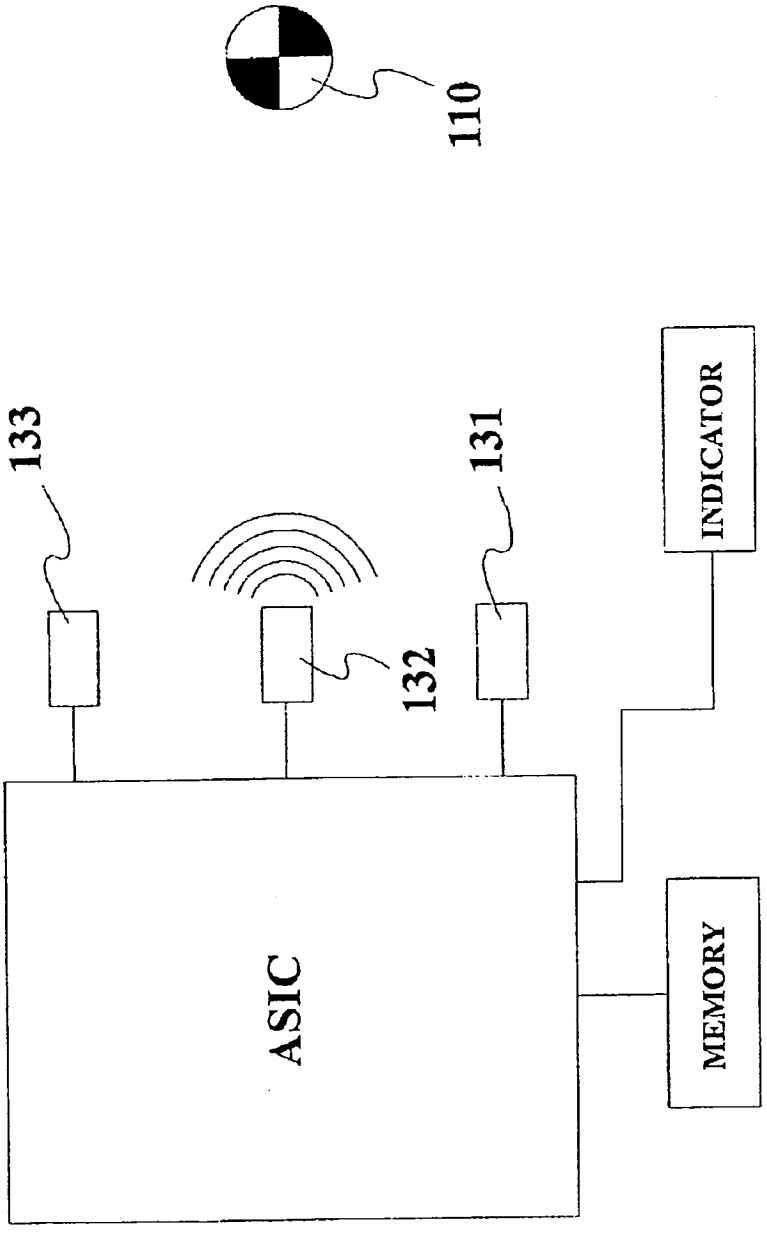

FIG. 7B

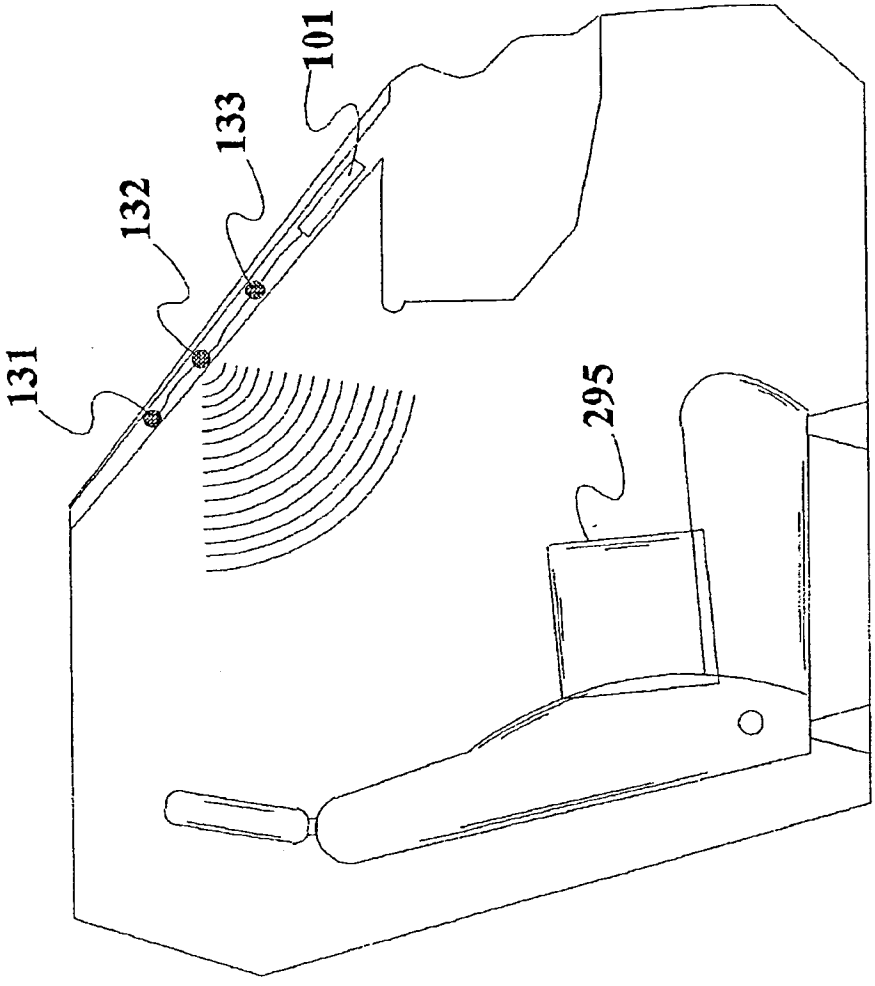

FIG. 8

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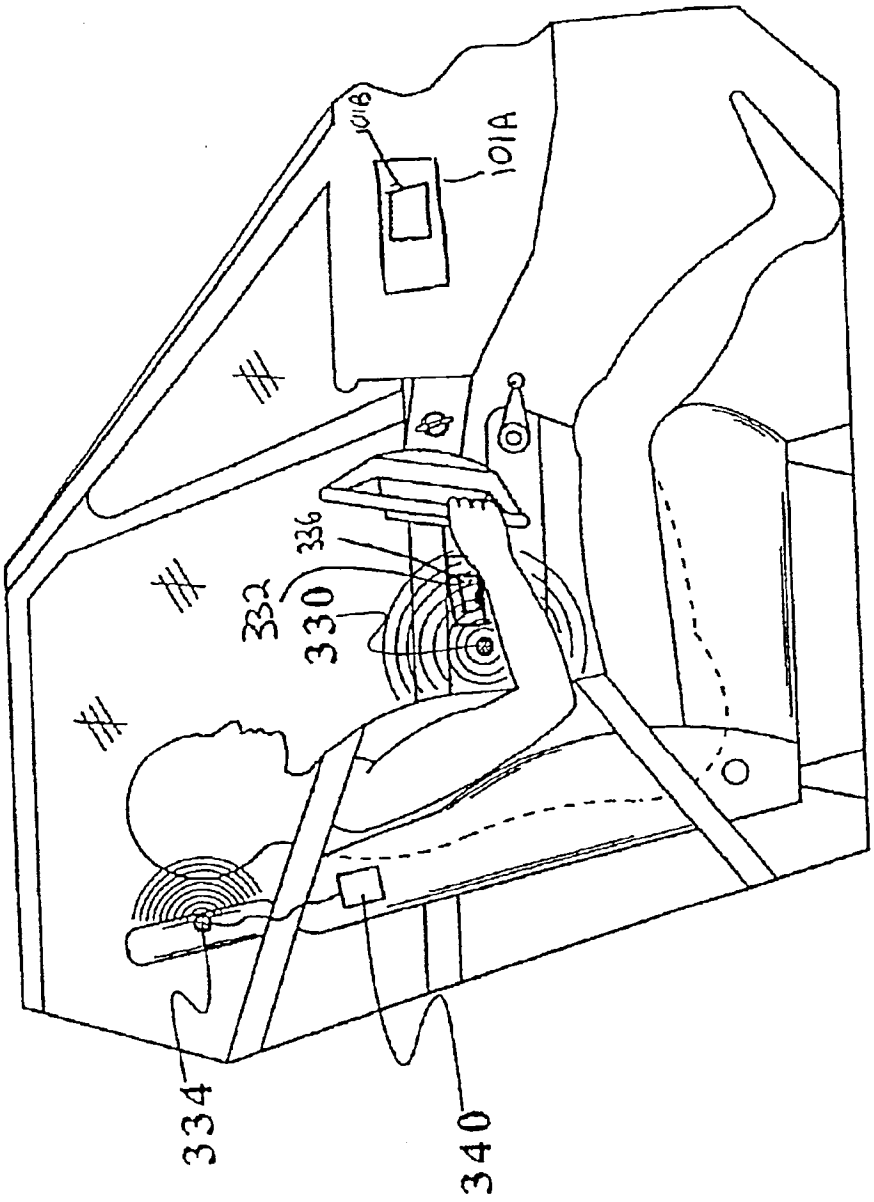

FIG. 9

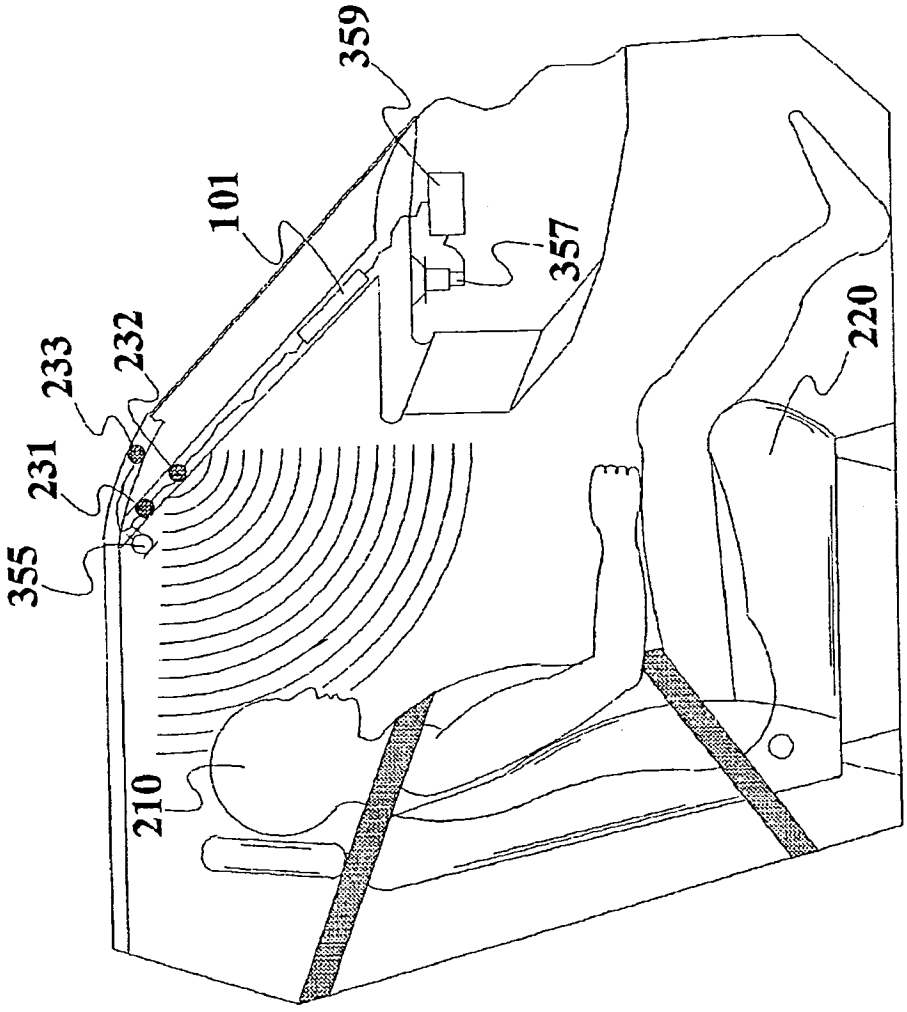

FIG. 10

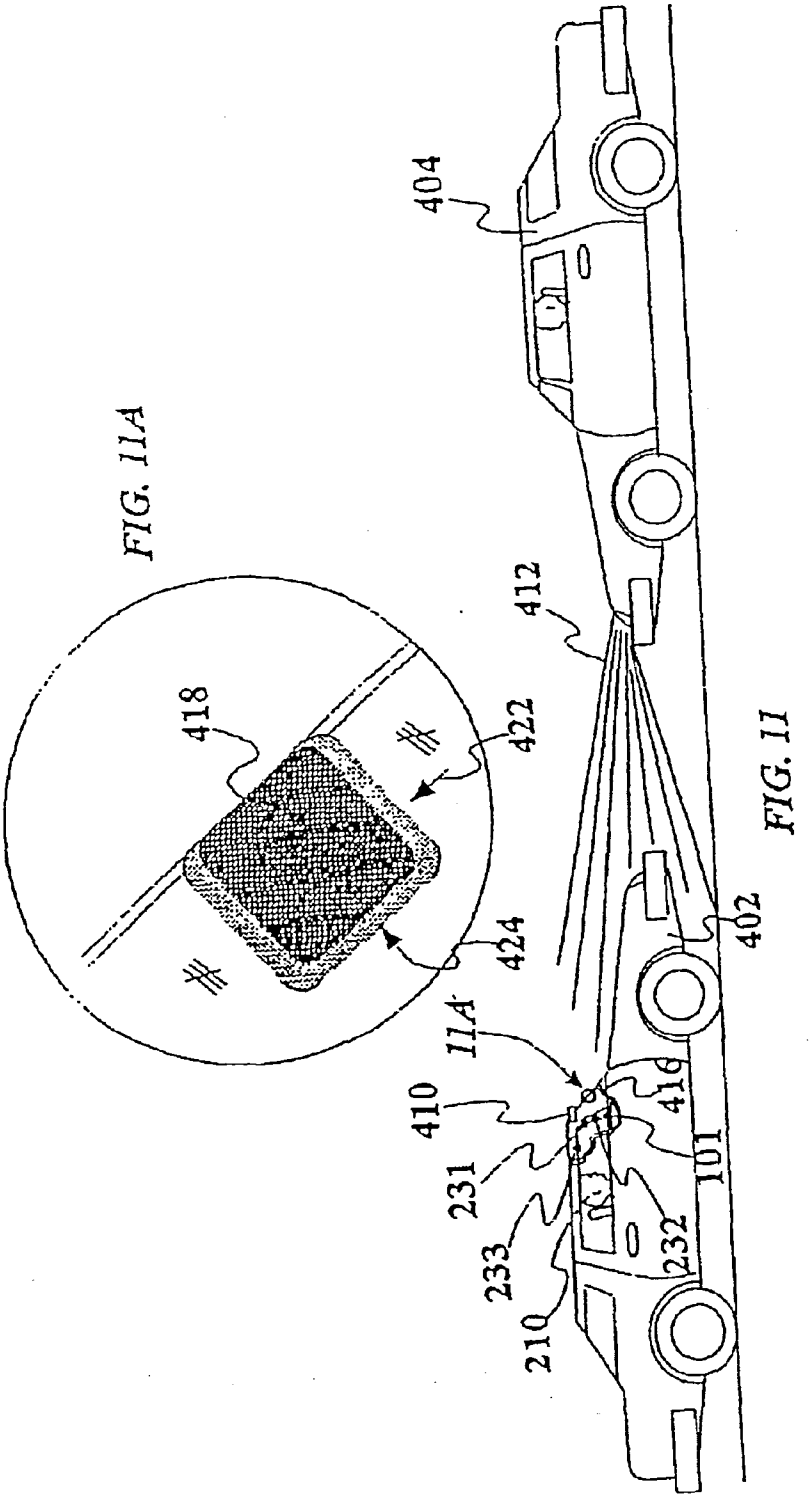

FIG. 11A

FIG. 11

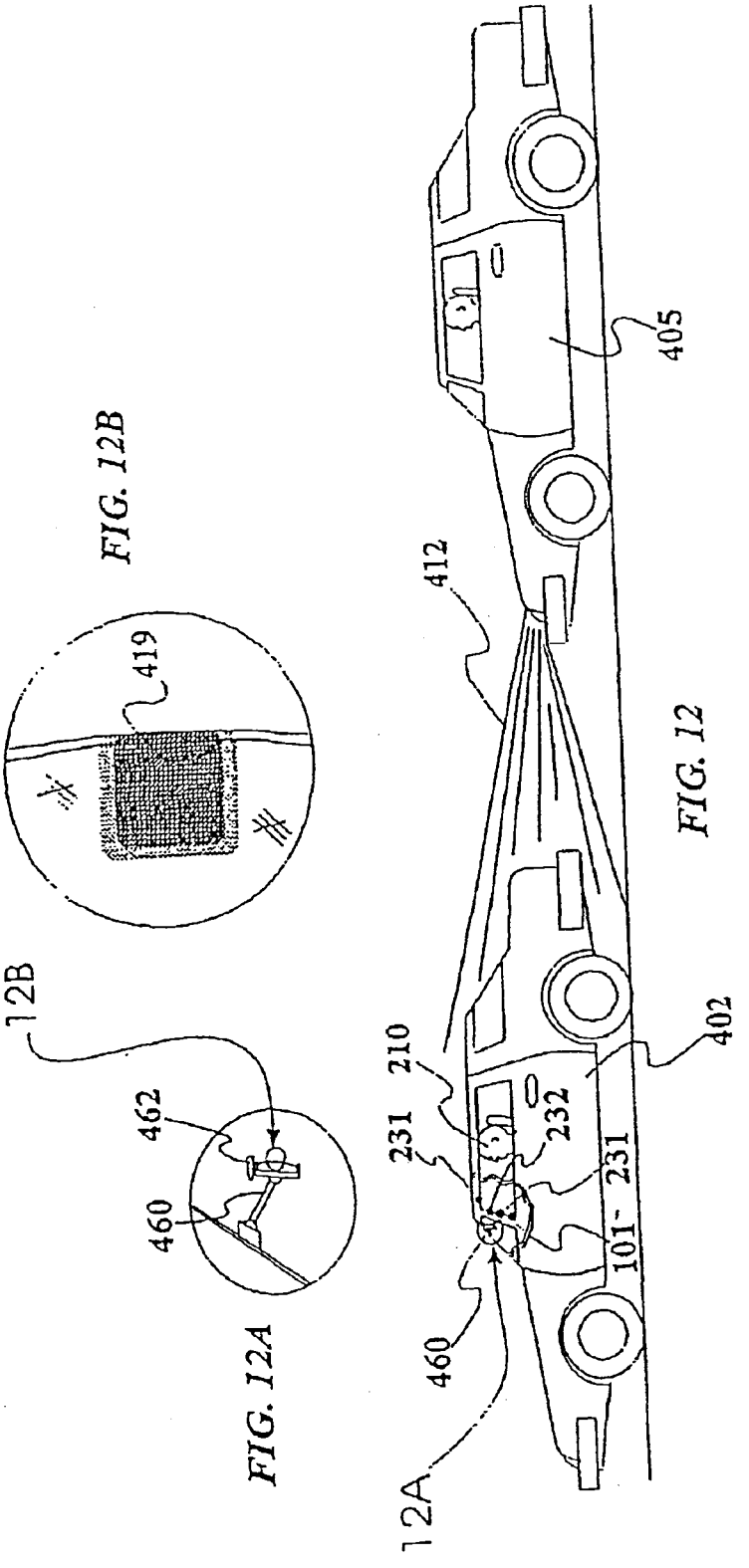

FIG. 12B

FIG. 12A

FIG. 12

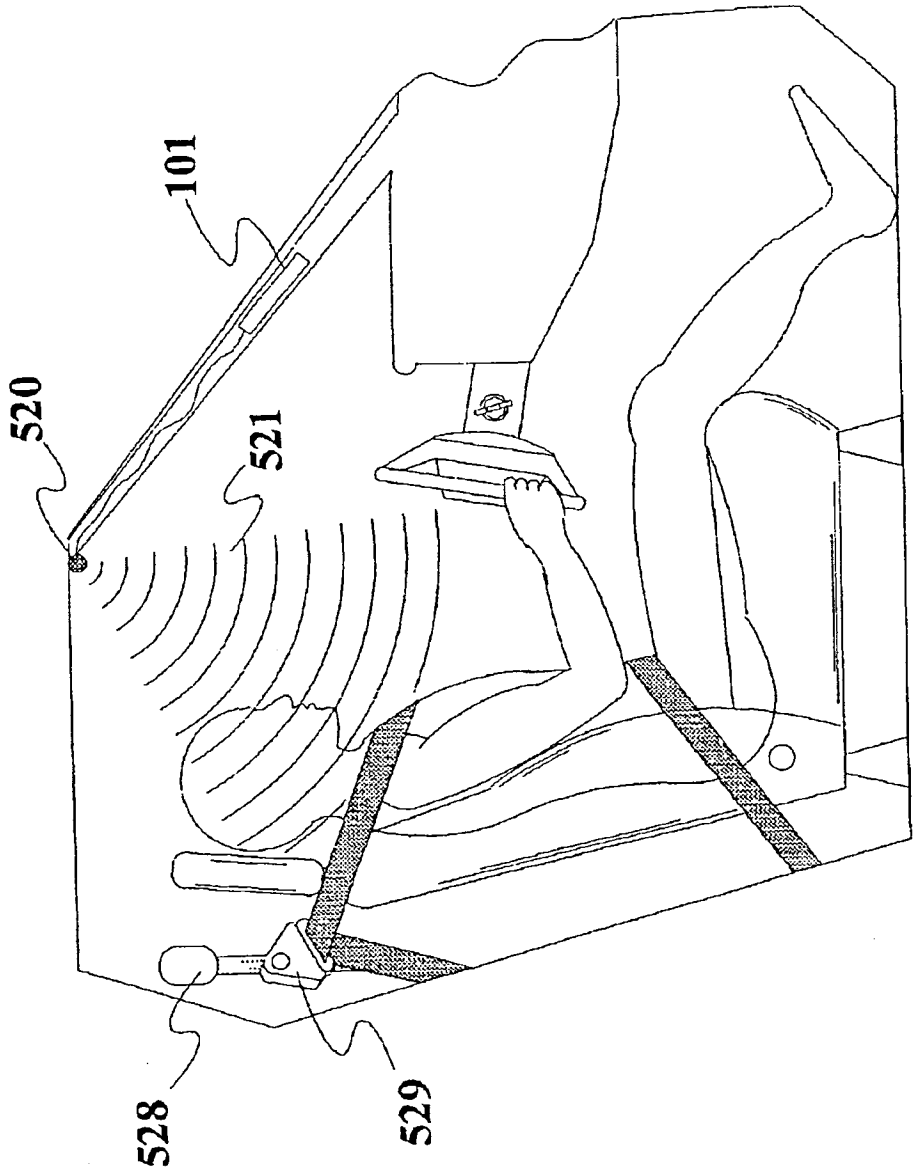

FIG. 13

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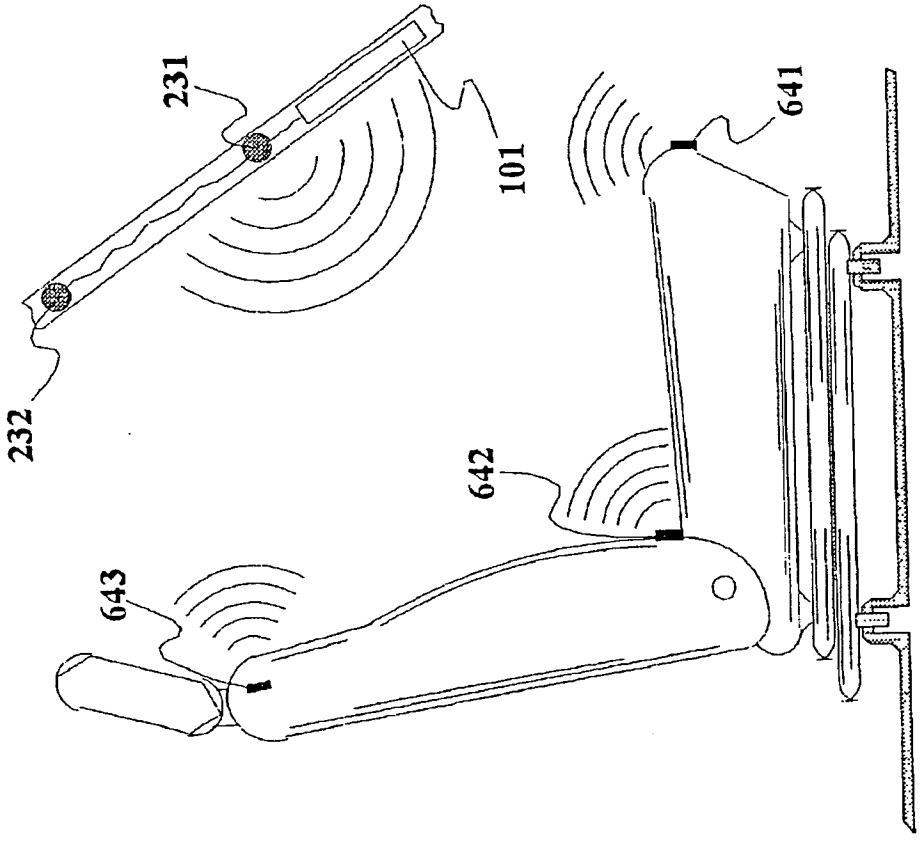

FIG. 14

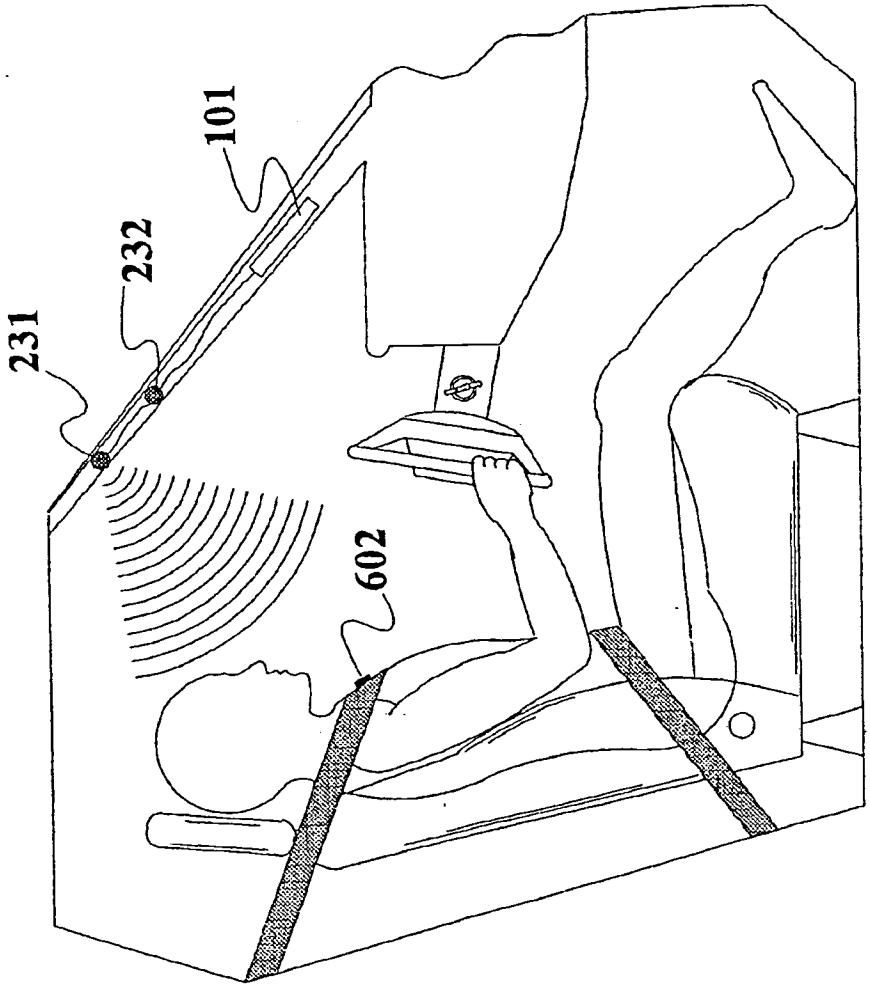

FIG. 15

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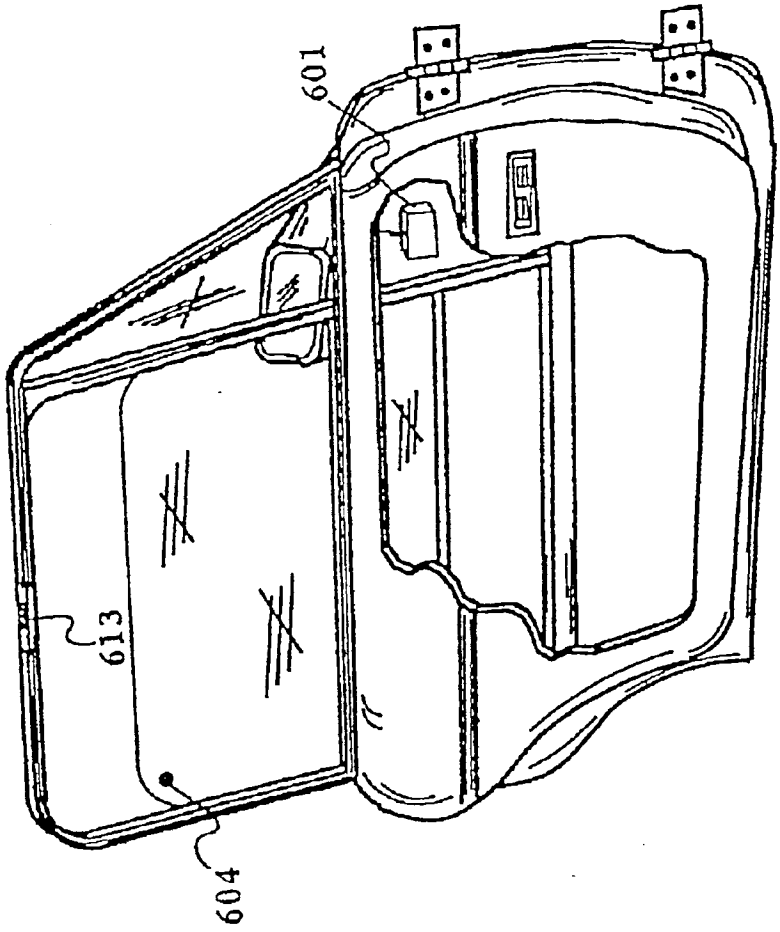

FIG. 16

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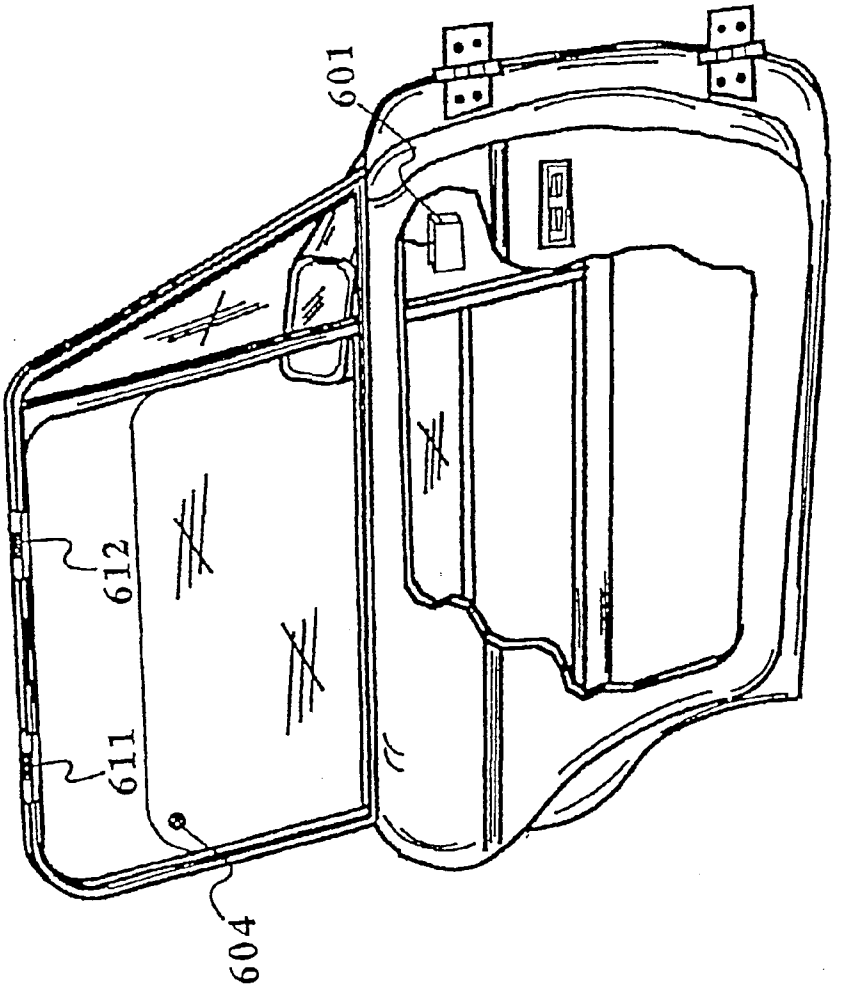

FIG. 16A

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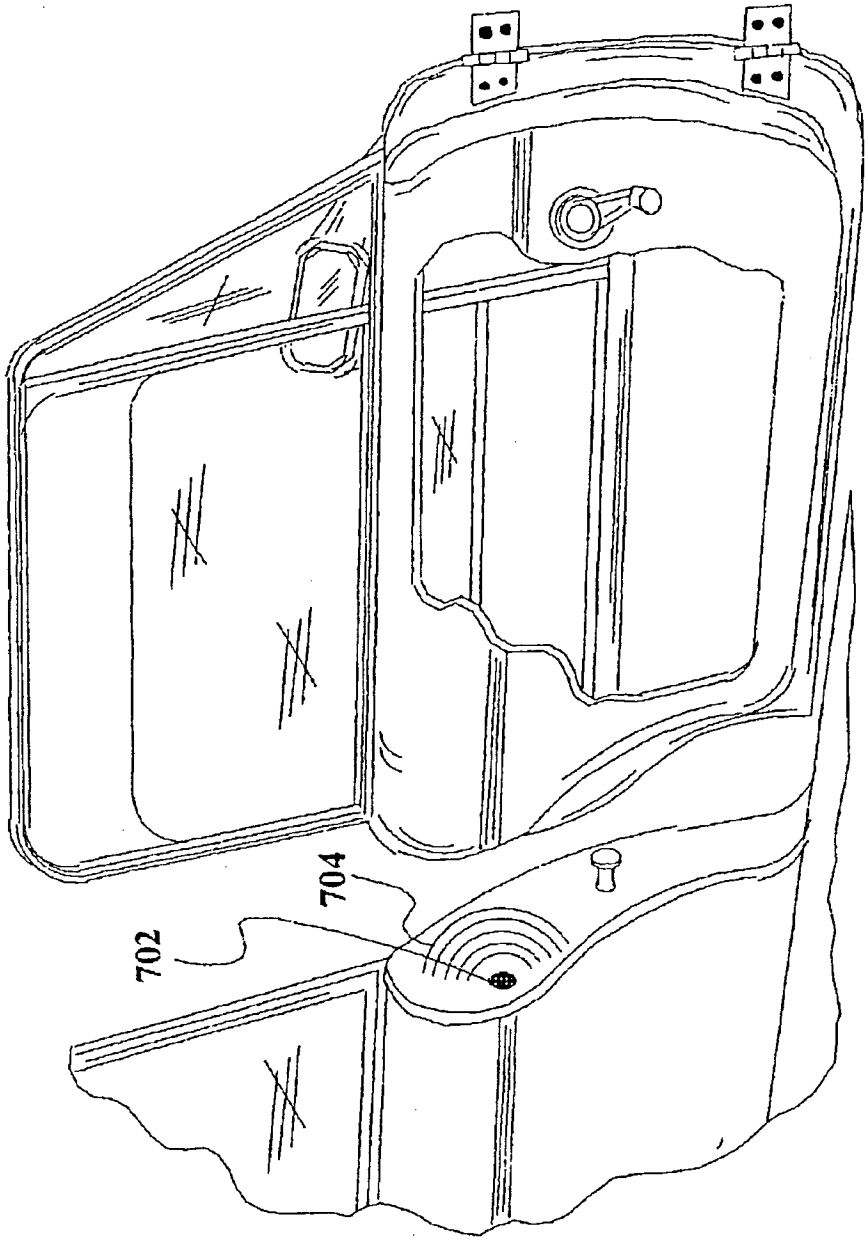

FIG. 17

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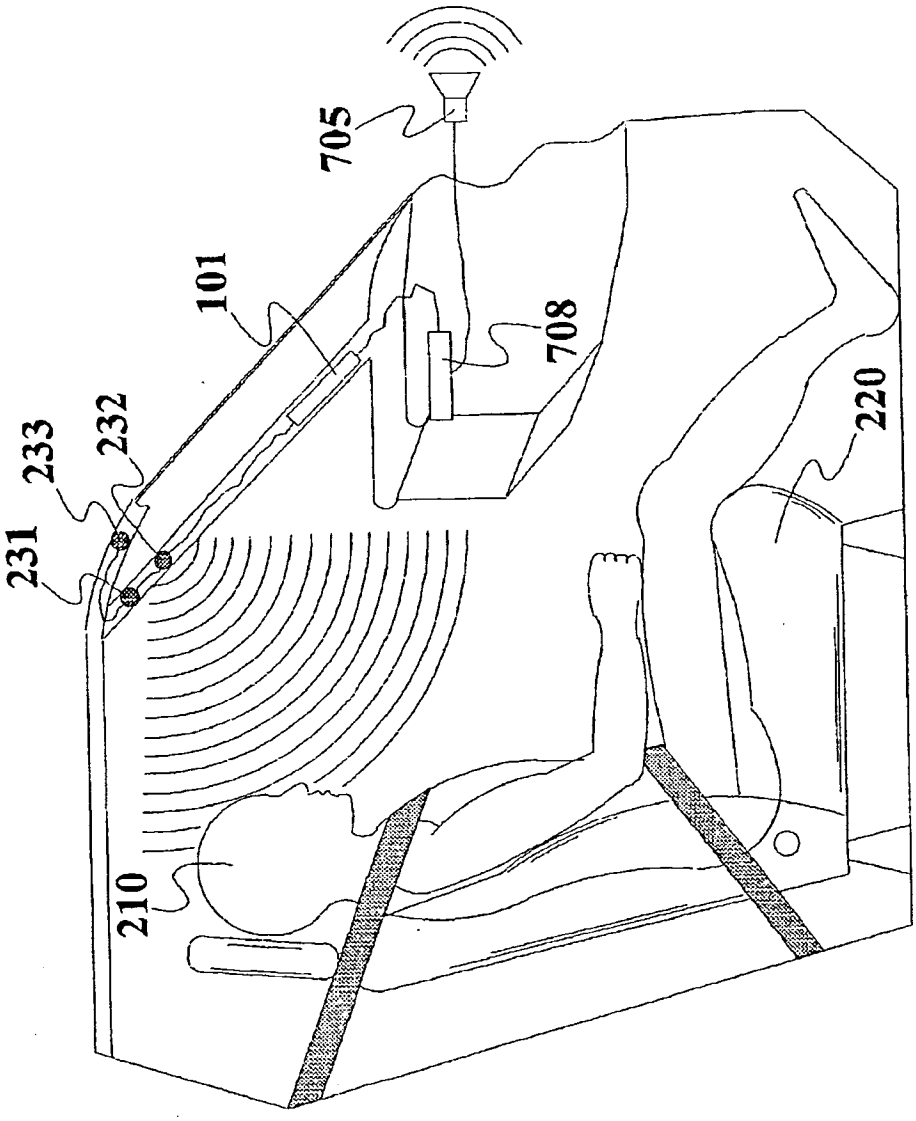

FIG. 18

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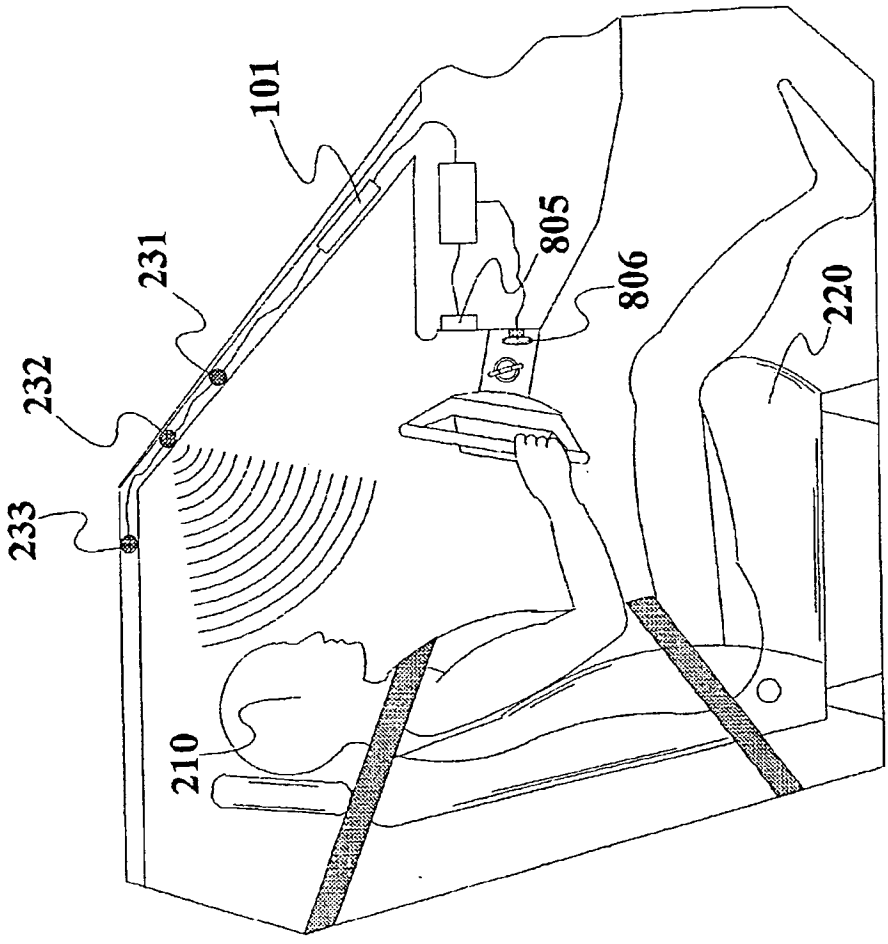

FIG. 19

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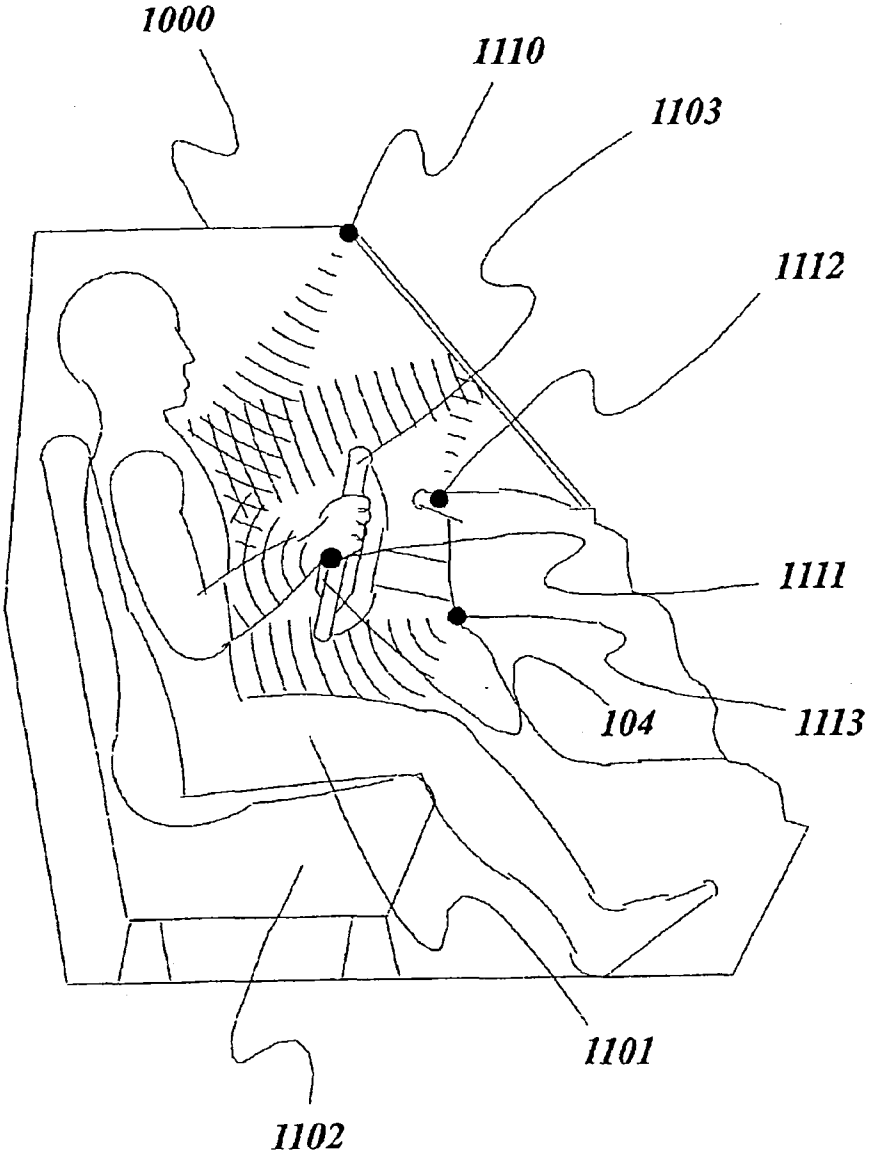

FIG. 20

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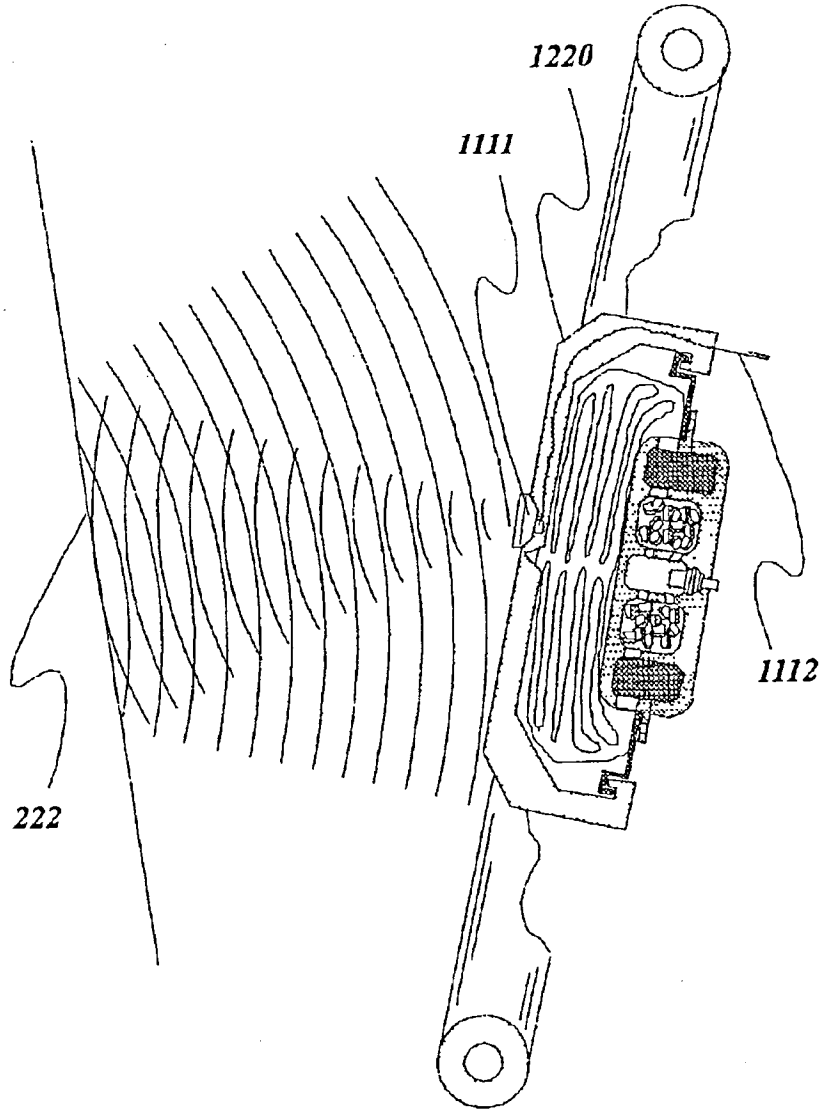

FIG. 21

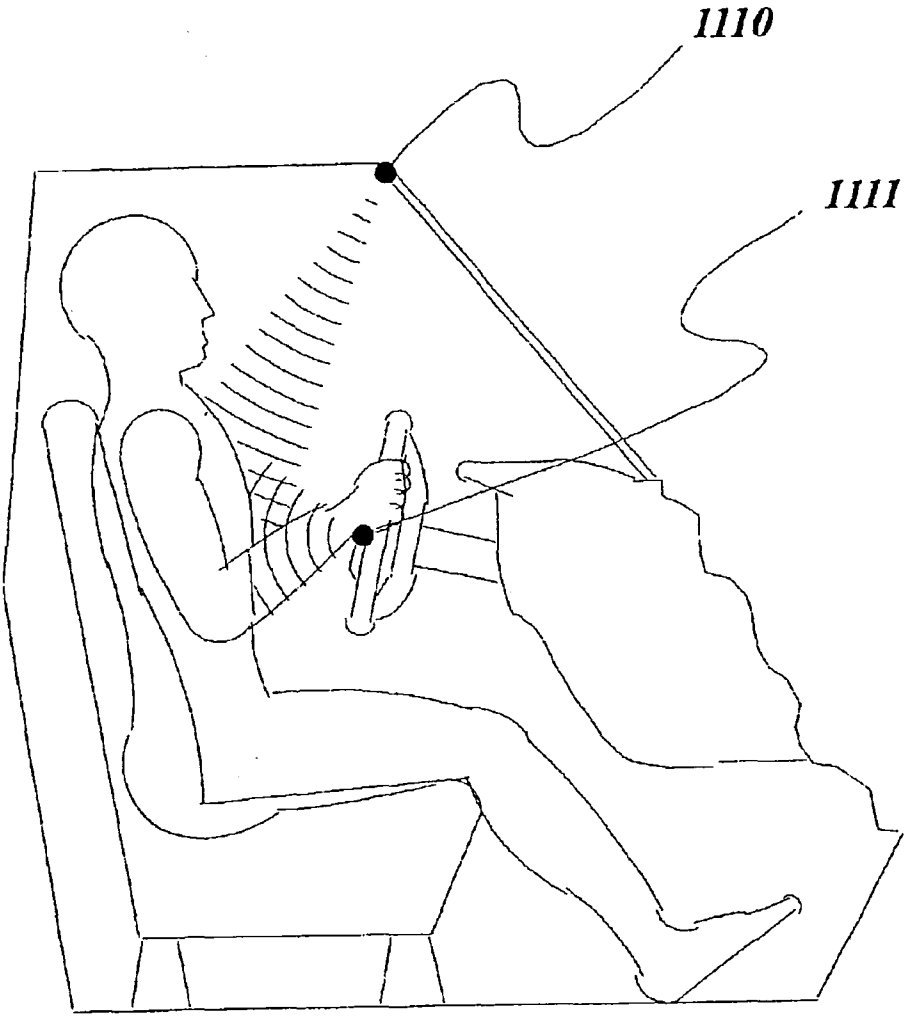

FIG. 22

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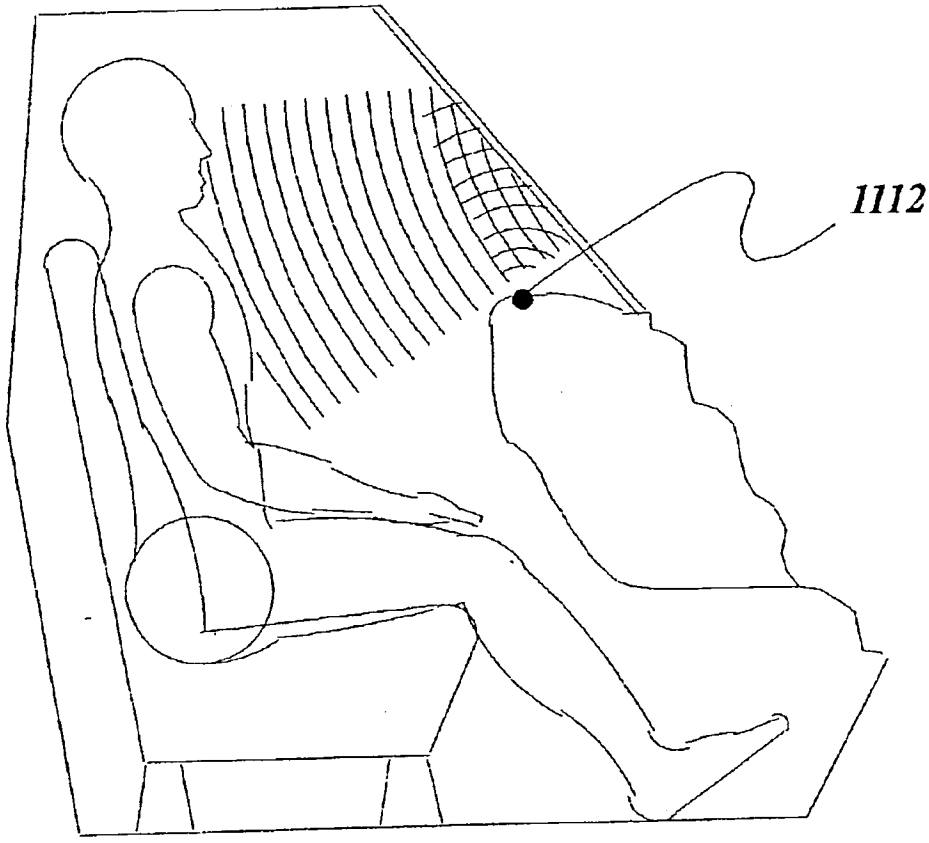

FIG. 23

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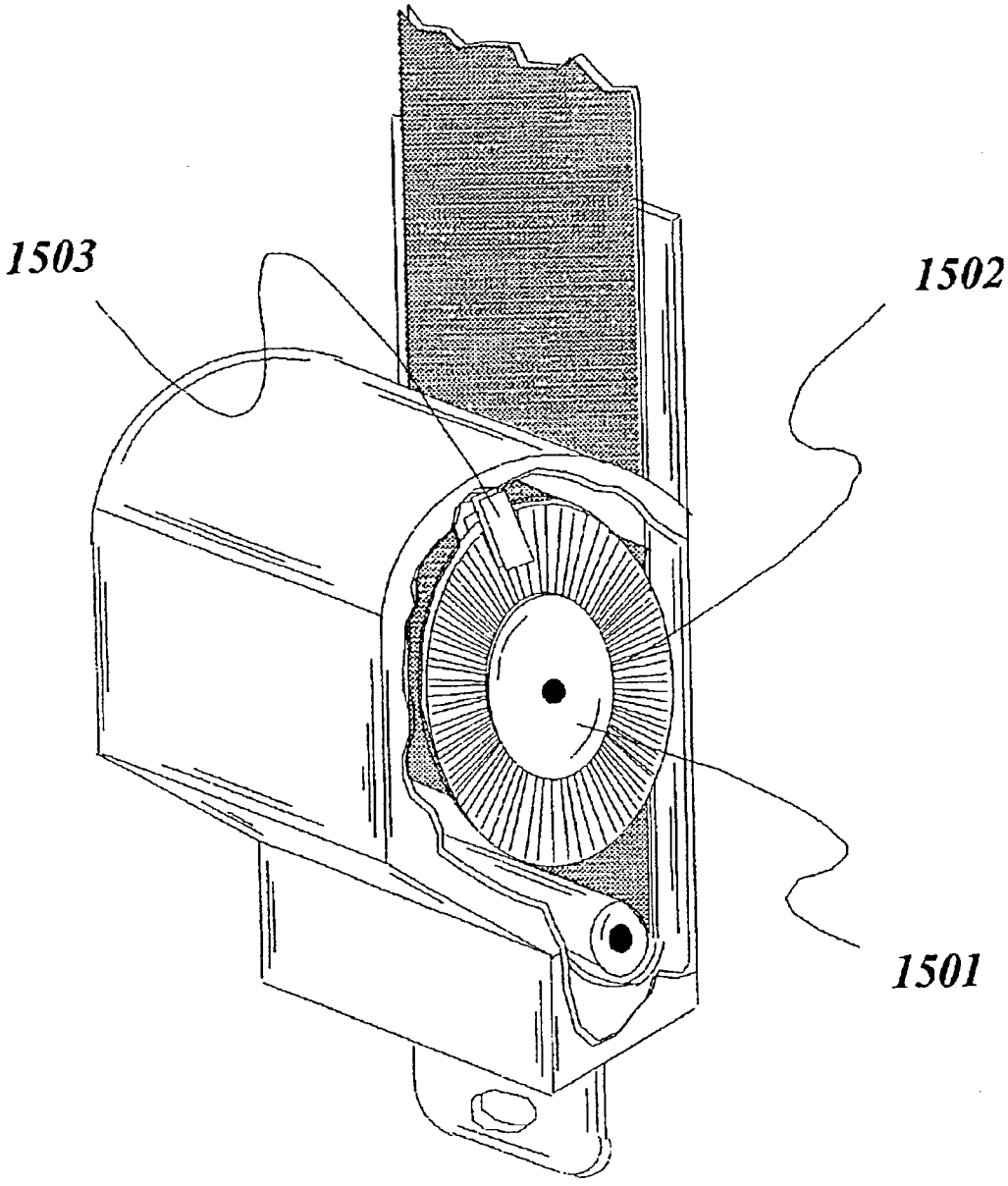

FIG. 24

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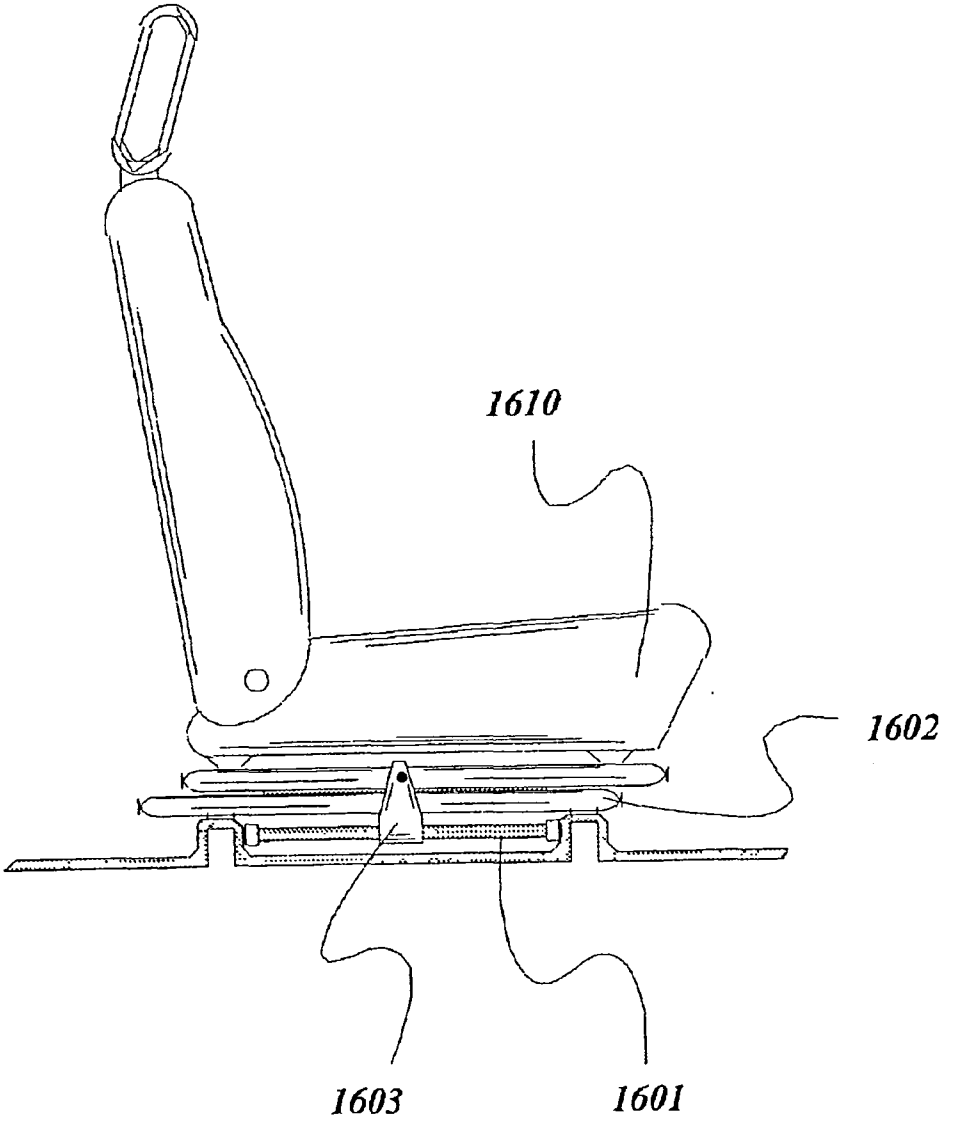

FIG. 25

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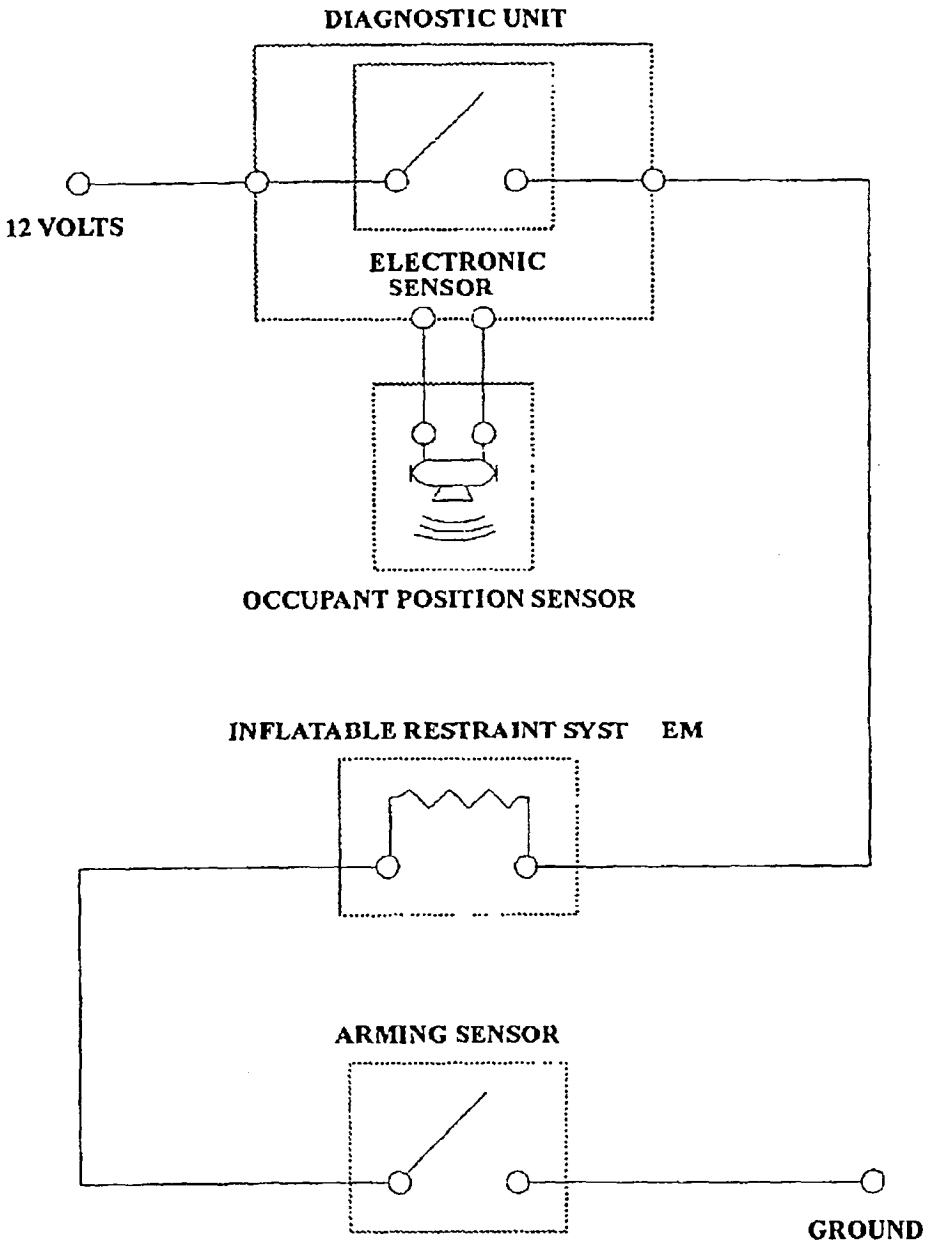
DIAGNOSTIC UNIT
12 VOLTS
ELECTRONIC SENSOR
OCCUPANT POSITION SENSOR
INFLATABLE RESTRAINT SYST EM
ARMING SENSOR
GROUND

FIG. 26

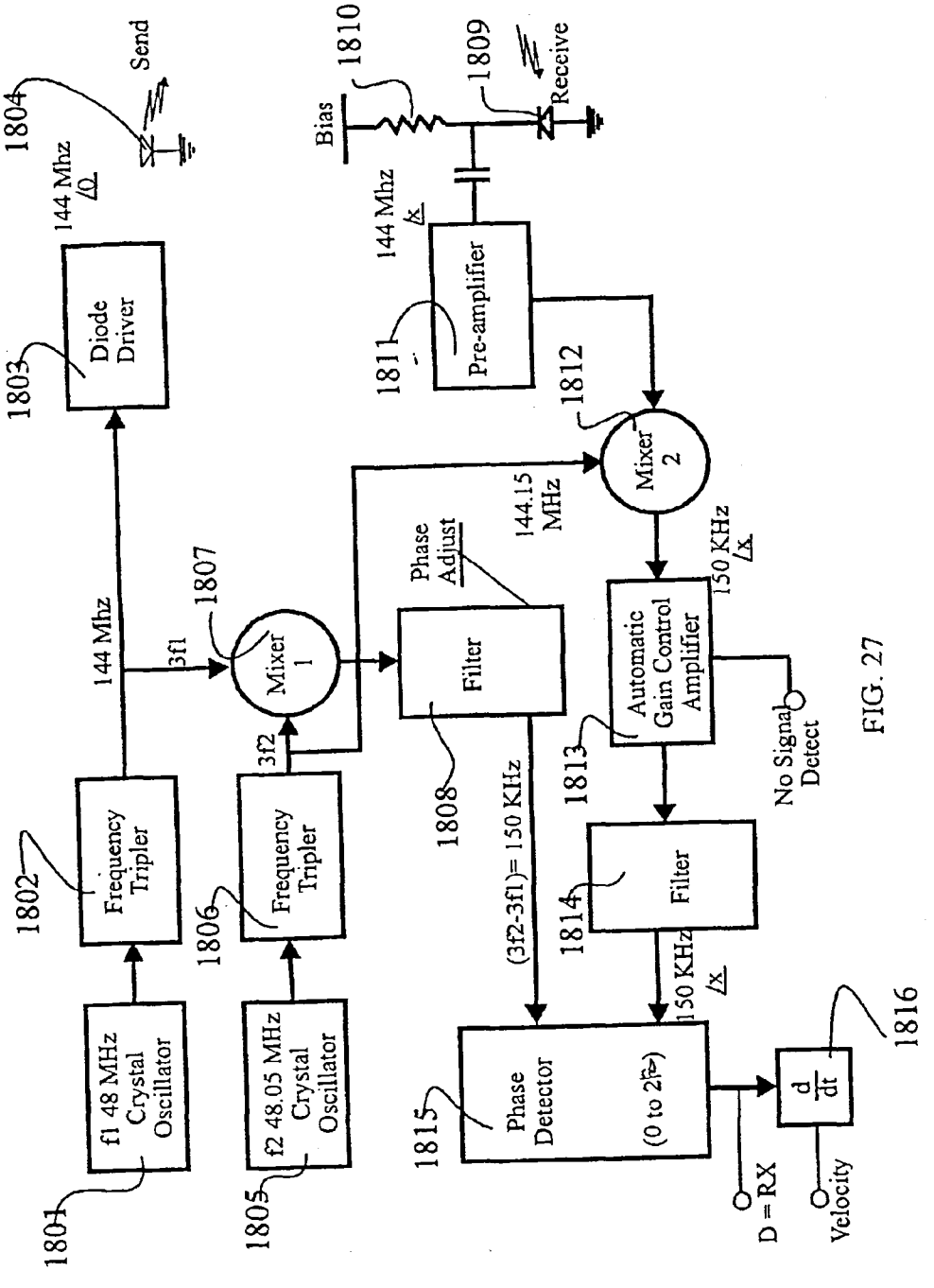
1804
Send
144 Mhz
Ω
1803
Diode Driver
1810
Bias
1809
Receive
144 Mhz
λ
1811
Pre-amplifier
1812
Mixer 2
144.15 MHz
Phase Adjust
144 Mhz
1807
3f1
Mixer 1
Filter
Automatic Gain Control Amplifier
150 KHz
λ
3f2
1808
1813
No Signal Detect
1802
Frequency Tripler
1806
Frequency Tripler
(3f2-3f1)= 150 KHz
1814
Filter
150 KHz
λ
f1 48 MHz Crystal Oscillator
f2 48.05 MHz Crystal Oscillator
1815
Phase Detector
(0 to 2π)
d/dt
1816
1801
1805
D = RX
Velocity

FIG. 27

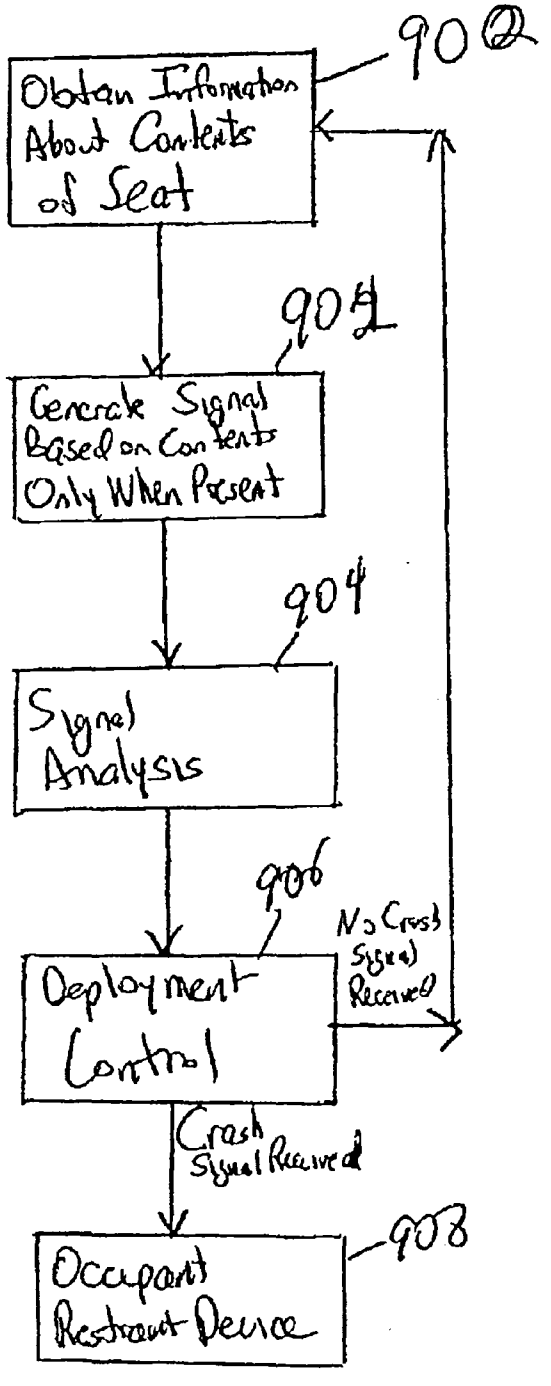
902
Obtain Information About Contents of Seat
904
Generate Signal Based on Contents Only When Present
904
Signal Analysis
906
Deployment Control
No Crash Signal Received
Crash Signal Received
908
Occupant Restraint Device

FIG. 28

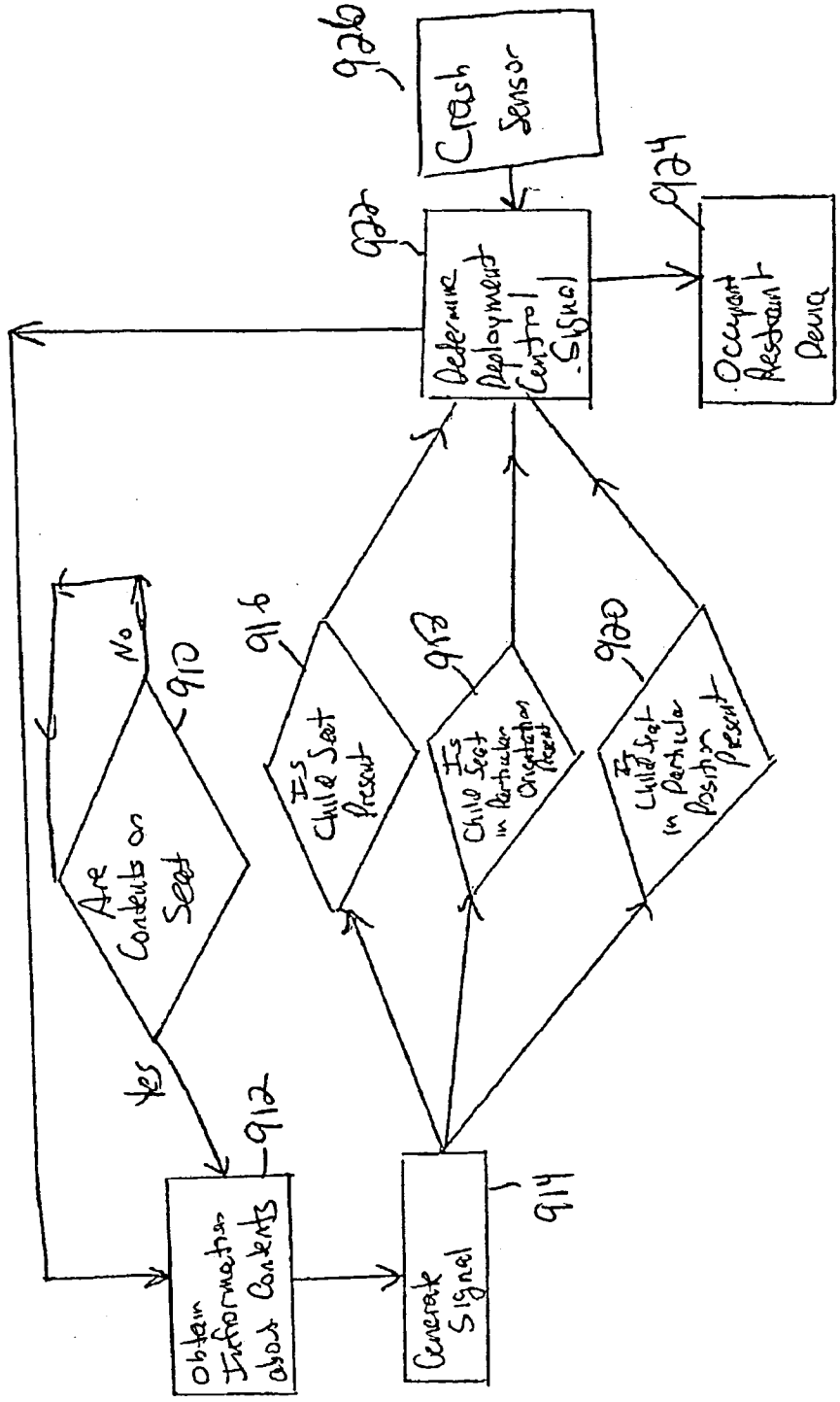
926
Crash Sensor
922
Determine Deployment Control Signal
924
Occupant Restraint Device
916
Is Child Seat Present
918
Is Child Seat in Particular Orientation
920
Is Child Seat in Particular Position
910
Are Contents on Seat
No
Yes
912
Obtain Information about Contents
914
Generate Signal

FIG. 29

OCCUPANT RESTRAINT DEVICE CONTROL SYSTEM AND METHOD

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Ser. No. 10/058,706 filed Jan. 28, 2002 which in turn is:

1) a continuation-in-part of U.S. patent application Ser. No. 09/891,432 filed Jun. 26, 2001 now U.S. Pat. No. 6,513,853, which in turn is a continuation-in-part of U.S. patent application Ser. No. 09/838,920 filed Apr. 20, 2001 now U.S. Pat. No. 6,778,672, which in turn is a continuation-in-part of U.S. patent application Ser. No. 09/563,556 filed May 3, 2000 now U.S. Pat. No. 6,474,683, which is a continuation-in-part of U.S. patent application Ser. No. 09/437,535 filed Nov. 10, 1999 now U.S. Pat. No. 6,712,387 which in turn is a continuation-in-part of U.S. patent application Ser. No. 09/047,703 filed Mar. 25, 1998, now U.S. Pat. No. 6,039,139, which in turn is:
   a) a continuation-in-part of U.S. patent application Ser. No. 08/640,068 filed Apr. 30, 1996, now U.S. Pat. No. 5,829,782, which in turn is a continuation of U.S. patent application Ser. No. 08/239,978 filed May 9, 1994, now abandoned, which in turn is a continuation-in-part of U.S. patent application Ser. No. 08/040,978 filed Mar. 31, 1993, now abandoned, which in turn is a continuation-in-part of U.S. patent application Ser. No. 07/878,571 filed May 5, 1992, now abandoned; and
   b) a continuation-in-part of U.S. patent application Ser. No. 08/905,876 filed Aug. 4, 1997, now U.S. Pat. No. 5,848,802 , which in turn is a continuation of U.S. patent application Ser. No. 08/505,036 filed Jul. 21, 1995, now U.S. Pat. No. 5,653,462, which in turn is a continuation of the 08/040,978 application filed on Mar. 31, 1993, now abandoned which in turn is a continuation-in-part of the Ser. No. 07/878,571 application filed on May 5, 1992, now abandoned;
2) a continuation-in-part of U.S. patent application Ser. No. 09/639,299 filed Aug. 15, 2000 which is:
   (a) a continuation-in-part of U.S. patent application Ser. No. 08/905,877 filed Aug. 4, 1997, now U.S. Pat. No. 6,186,537; which is a continuation of U.S. patent application Ser. No. 08/505,036 filed Jul. 25, 1995, now U.S. Pat. No. 5,653,462; which is a continuation of U.S. patent application Ser. No. 08/040,978 filed Mar. 31, 1993, now abandoned; which is a continuation-in-part of U.S. patent application Ser. No. 07/878,571 filed May 5, 1992, now abandoned;
   (b) a continuation-in-part of U.S. patent application Ser. No. 09/409,625 filed Oct. 1, 1999, now U.S. Pat. No. 6,270,116, which is a continuation-in-part of U.S. patent application Ser. No. 08/905,877 filed Aug. 4, 1997, now U.S. Pat. No. 6,186,537; which is a continuation of U.S. patent application Ser. No. 08/505,036 filed Jul. 25, 1995, now U.S. Pat. No. 5,653,462; which is a continuation of U.S. patent application Ser. No. 08/040,978 filed Mar. 31, 1993, now abandoned; which is a continuation-in-part of U.S. patent application Ser. No. 07/878,571 filed May 5, 1992, now abandoned;
   (c) a continuation-in-part of U.S. patent application Ser. No. 09/448,337 filed Nov. 23, 1999, now U.S. Pat. No. 6,283,503, which is a continuation-in-part of U.S. patent application Ser. No. 08/905,877 filed Aug. 4, 1997, now U.S. Pat. No. 6,186,537; which is a continuation of U.S. patent application Ser. No. 08/505,036 filed Jul. 25, 1995, now U.S. Pat. No. 5,653,462; which is a continuation of U.S. patent application Ser. No. 08/040,978 filed Mar. 31, 1993, now abandoned; which is a continuation-in-part of U.S. patent application Ser. No. 07/878,571 filed May 5, 1992, now abandoned; and
   (d) a continuation-in-part of U.S. patent application Ser. No. 09/448,338 filed Nov. 23, 1999, now U.S. Pat. No. 6,168,186, which is a continuation-in-part of U.S. patent application Ser. No. 08/905,877 filed Aug. 4, 1997, now U.S. Pat. No. 6,186,537; which is a continuation of U.S. patent application Ser. No. 08/505,036 filed Jul. 25, 1995, now U.S. Pat. No. 5,653,462; which is a continuation of U.S. patent application Ser. No. 08/040,978 filed Mar. 31, 1993, now abandoned; which is a continuation-in-part of U.S. patent application Ser. No. 07/878,571 filed May 5, 1992, now abandoned; and
3) a continuation-in-part of U.S. patent application Ser. No. 09/543,678 filed Apr. 7, 2000 which is a continuation-in-part of U.S. patent application Ser. No. 09/047,704 filed Mar. 25, 1998, now U.S. Pat. No. 6,116,638, which in turn is:
   a) a continuation-in-part of U.S. patent application Ser. No. 08/640,068 filed Apr. 30, 1996, now U.S. Pat. No. 5,829,782, which in turn is a continuation of U.S. patent application Ser. No. 08/239,978 filed May 9, 1994, now abandoned, which in turn is a continuation-in-part of U.S. patent application Ser. No. 08/040,978 filed Mar. 31, 1993, now abandoned, which in turn is a continuation-in-part of U.S. patent application Ser. No. 07/878,571 filed May 5, 1992, now abandoned; and
   b) a continuation-in-part of U.S. patent application Ser. No. 08/905,876 filed Aug. 4, 1997, now U.S. Pat. No. 5,848,802, which in turn is a continuation of U.S. patent application Ser. No. 08/505,036 filed Jul. 21, 1995, now U.S. Pat. No. 5,653,462, which in turn is a continuation of the 08/040,978 application which in turn is a continuation-in-part of the 07/878,571 application.

This application is also related to (in view of common subject matter), but does not claim priority from, U.S. patent application Ser. No. 09/084,641 filed May 26, 1998, now U.S. Pat. No. 5,901,978, U.S. patent application Ser. No. 09/562,994 filed May 1, 2000, now, U.S. Pat. No. 6,254,127, U.S. patent application Ser. No. 09/891,665 filed Jun. 26, 2001, U.S. patent application Ser. No. 09/639,303 filed Aug. 16, 2000, and U.S. patent application Ser. No. 09/543,997 filed Apr. 6, 2000, now U.S. Pat. No. 6,234,520.

FIELD OF THE INVENTION

The present invention is related to methods and apparatus for detecting the presence of a child seat, more particularly, to methods and apparatus for detecting the presence of a child seat, its orientation and/or position. The detected presence, orientation and/or position, of a child seat may be used to control or affect the operation of a vehicular system, such as an occupant protection or restraint device, e.g., an airbag system.

The present invention relates generally to methods and arrangements for obtaining information about an occupying item in a vehicle or a part in the vehicle using a wave-detecting device which receives waves emanating from a

reflector or resonator. The reflector or resonator is arranged in association with the vehicle or occupying item so that the emanating therefrom can be processed to provide information about the occupying item, such as its position, or information about the vehicle, such as the position of the seat when the resonator is placed in the seat.

BACKGROUND OF THE INVENTION

It is a problem in vehicles that children and infants are sometimes left alone, either intentionally or inadvertently, and the temperature in the vehicle rises. The child or infant is suffocated by the lack of oxygen in the vehicle. This same problem also arises for pets which are more often left alone in a hot vehicle without adequate ventilation.

Another problem which has unfortunately arisen relates to the theft of vehicles. There have been incidents when a thief waits in a vehicle until the driver of the vehicle enters the vehicle and then forces the driver to provide the keys to the vehicle and exit the vehicle.

As for additional background, in 1984, the National Highway Traffic Safety Administration (NHTSA) of the U.S. Department of Transportation issued a requirement for frontal crash protection of automobile occupants. This regulation mandated "passive occupant restraints" for all passenger cars by 1992. A more recent regulation required both driver and passenger side airbags on all passenger cars and light trucks by 1998. In addition, the demand for airbags is constantly accelerating in both Europe and Japan and all vehicles produced in these areas and eventually worldwide will likely be equipped with airbags as standard equipment, if they do not include them already.

Whereas thousands of lives have been saved by airbags, significant improvements can be made. As discussed in detail in U.S. Pat. No. 5,653,462 referenced above, and incorporated herein by reference, for a variety of reasons, vehicle occupants can be or get too close to the airbag before it deploys and can be seriously injured or killed upon deployment of the airbag.

Also, a child in a rear facing child seat, which is placed on the right front passenger seat, is in danger of being seriously injured if the passenger airbag deploys. This has now become an industry-wide concern and the U.S. automobile industry is continually searching for an easy, economical solution, which will prevent the deployment of the passenger side airbag if a rear facing child seat is present. An improvement on the invention disclosed in the above-referenced patent, as will be disclosed in greater detail below, includes more sophisticated means to identify objects within the passenger compartment and will solve this problem.

Initially, these systems will solve the out-of-position occupant and the rear facing child seat problems related to current airbag systems and prevent unneeded deployments when a seat is unoccupied. Airbags are now under development to protect rear seat occupants in vehicle crashes. A system is therefore needed to detect the presence of occupants, position, i.e., determine if they are out-of-position, and type, e.g., to identify the presence of a rear facing child seat in the rear seat. Current and future automobiles may have eight or more airbags as protection is sought for rear seat occupants and from side impacts. In addition to eliminating the disturbance of unnecessary airbag deployments, the cost of replacing these airbags will be excessive if they all deploy in an accident. The improvements described below minimize this cost by not deploying an airbag for a seat, which is not occupied by a human being. An occupying item of a seat may be a living occupant such as a human being or dog, another living organism such as a plant, or an inanimate object such as a box or bag of groceries.

A device to monitor the vehicle interior and identify its contents is needed to solve these and many other problems. For example, once a Vehicle Interior Identification and Monitoring System (VIMS) for identifying and monitoring the contents of a vehicle is in place, many other products become possible including the following:

Inflators and control systems now exist which will adjust the amount of gas flowing into and/or out of the airbag to account for the size and position of the occupant and for the severity of the accident. The vehicle identification and monitoring system of this invention will control such systems based on the presence and position of vehicle occupants or the presence, position and orientation of an occupied child seat.

Side impact airbag systems began appearing on 1995 vehicles. The danger of deployment-induced injuries will exist for side impact airbags as they now do for frontal impact airbags. A child with his head against the airbag is such an example. The system of this invention will minimize such injuries.

Vehicles can be provided with a standard cellular phone as well as the Global Positioning System (GPS), an automobile navigation or location system with an optional connection to a manned assistance facility, which is now available on at least one vehicle model. In the event of an accident, the phone may automatically call 911 for emergency assistance and report the exact position of the vehicle. If the vehicle also has a system as described below for monitoring each seat location, the number and perhaps the condition of the occupants could also be reported. In that way, the emergency service (EMS) would know what equipment and how many ambulances to send to the accident site. Moreover, a communication channel can be opened between the vehicle and a monitoring facility/emergency response facility or personnel to enable directions to be provided to the occupant(s) of the vehicle to assist in any necessary first aid prior to arrival of the emergency assistance personnel.

Vehicle entertainment system engineers have stated that the quality of the sound in the vehicle could be improved if the number, size and location of occupants and other objects were known. However, it is not believed that, prior to the instant invention, they have thought to determine the number, size and/or location of the occupants and use such determination in combination with the entertainment system. Indeed, this information can be provided by the vehicle interior identification and monitoring system of this invention to thereby improve a vehicle's entertainment system.

Similarly to the entertainment system, the heating, ventilation and air conditioning system (HVAC) could be improved if the number, attributes and location of vehicle occupants were known. This can be used to provide a climate control system tailored to each occupant, for example, or the system can be turned off for certain seat locations if there are no occupants present at those locations.

In some cases, the position of a particular part of the occupant is of interest such as: (a) his hand or arm and whether it is in the path of a closing window so that the motion of the window needs to be stopped; (b) the position of the shoulder so that the seat belt anchorage point can be adjusted for the best protection of the occupant; or, (c) the position of the rear of the occupants head so that the headrest can be adjusted to minimize whiplash injuries in rear impacts.

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The above applications illustrate the wide range of opportunities, which become available if the identity and location of various objects and occupants, and some of their parts, within the vehicle were known. Once the system is operational, it would be logical for the system to also incorporate the airbag electronic sensor and diagnostics system (SDM) since it needs to interface with SDM anyway and since they could share computer capabilities which will result in a significant cost saving to the auto manufacturer. For the same reasons, it would be logical for VIMS to include the side impact sensor and diagnostic system. As the VIMS improves to where such things as the exact location of the occupants ears and eyes can be determined, even more significant improvements to the entertainment system become possible through the use of noise canceling sound, and the rear view mirror can be automatically adjusted for the driver's eye location. Another example involves the monitoring of the driver's behavior over time which can be used to warn a driver if he or she is falling asleep, or to stop the vehicle if the driver loses the capacity to control it.

Using an advanced VIMS, as explained below, the position of the driver's eyes can be accurately determined and portions of the windshield can be selectively darkened to eliminate the glare from the sun or oncoming vehicle headlights. This system uses electro-chromic glass, a liquid crystal device, or other appropriate technology, and detectors to detect the direction of the offending light source. In addition to eliminating the glare, the sun visor can now also be eliminated.

The present invention adds more sophisticated pattern recognition capabilities such as fuzzy logic systems, neural network systems or other pattern recognition computer based algorithms to the occupant position measurement system disclosed in the above referenced patents and/or patent applications and greatly extends the areas of application of this technology. An example of such a pattern recognition system using neural networks using sonar is discussed in two papers by Gorman, R. P. and Sejnowski, T. J. "Analysis of Hidden Units in a Layered Network Trained to Classify Sonar Targets", *Neural Networks*, Vol. 1. pp. 75–89, 1988, and "Learned Classification of Sonar Targets Using a Massively Parallel Network", IEEE Transactions on Acoustics, Speech, and Signal Processing, Vol. 36, No. 7, July 1988.

Preferred embodiments of the invention are described below and unless specifically noted, it is the applicants' intention that the words and phrases in the specification and claims be given the ordinary and accustomed meaning to those of ordinary skill in the applicable art(s). If the applicant intends any other meaning, he will specifically state he is applying a special meaning to a word or phrase.

Likewise, applicants' use of the word "function" here is not intended to indicate that the applicants seek to invoke the special provisions of 35 U.S.C. §112, sixth paragraph, to define their invention. To the contrary, if applicants wish to invoke the provisions of 35 U.S.C. §112, sixth paragraph, to define their invention, they will specifically set forth in the claims the phrases "means for" or "step for" and a function, without also reciting in that phrase any structure, material or act in support of the function. Moreover, even if applicants invoke the provisions of 35 U.S.C. §112, sixth paragraph, to define their invention, it is the applicants' intention that their inventions not be limited to the specific structure, material or acts that are described in the preferred embodiments herein. Rather, if applicants claim their inventions by specifically invoking the provisions of 35 U.S.C. §112, sixth paragraph, it is nonetheless their intention to cover and include any and all structure, materials or acts that perform the claimed function, along with any and all known or later developed equivalent structures, materials or acts for performing the claimed function.

"Pattern recognition" as used herein will generally mean any system which processes a signal that is generated by an object, or is modified by interacting with an object, in order to determine which one of a set of classes that the object belongs to. Such a system might determine only that the object is or is not a member of one specified class, or it might attempt to assign the object to one of a larger set of specified classes, or find that it is not a member of any of the classes in the set. The signals processed are generally electrical signals coming from transducers which are sensitive to either acoustic or electromagnetic radiation and if electromagnetic, they can be either visible light, infrared, ultraviolet, radar or other part of the electromagnetic spectrum.

"To identify" as used herein will generally mean to determine that the object belongs to a particular set or class. The class may be one containing all rear facing child seats, one containing all human occupants, all human occupants not sitting in a rear facing child seat, or all humans in a certain height or weight range depending on the purpose of the system. In the case where a particular person is to be recognized, the set or class will contain only a single element, the person to be recognized.

Some Examples Follow:

In a passive infrared system a detector receives infrared radiation from an object in its field of view, in this case the vehicle occupant, and determines the temperature of the occupant based on the infrared radiation. The VIMS can then respond to the temperature of the occupant, which can either be a child in a rear facing child seat or a normally seated occupant, to control some other system. This technology could provide input data to a pattern recognition system but it has limitations related to temperature. The sensing of the child could pose a problem if the child is covered with blankets. It also might not be possible to differentiate between a rear facing child seat and a forward facing child seat. In all cases, the technology will fail to detect the occupant if the ambient temperature reaches body temperature as it does in hot climates. Nevertheless, for use in the control of the vehicle climate, for example, a passive infrared system that permits an accurate measurement of each occupant's temperature is useful.

In a laser optical system an infrared laser beam is used to momentarily illuminate an object, occupant or child seat in the manner as described, and illustrated in FIG. 8, of U.S. Pat. No. 5,653,462 cross-referenced above. In some cases, a charge-coupled device (a type of TV camera also referred to as a CCD array) or a CMOS device is used to receive the reflected light. The laser can either be used in a scanning mode, or, through the use of a lens, a cone of light can be created which covers a large portion of the object. Also triangulation can be used in conjunction with an offset scanning laser to determine the range of the illuminated spot from the light detector. In each case, a pattern recognition system, as defined above, is used to identify and classify, and can be used to locate, the illuminated object and its constituent parts. This system provides the most information about the object and at a rapid data rate. Its main drawback is cost which is considerably above that of ultrasonic or passive infrared systems. As the cost of lasers comes down in the future, this system will become more competitive. Depending on the implementation of the system, there may

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be some concern for the safety of the occupant if the laser light can enter the occupant's eyes. This is minimized if the laser operates in the infrared spectrum.

Radar systems have similar properties to the laser system discussed above. The wavelength of a particular radar system can limit the ability of the pattern recognition system to detect object features smaller than a certain size. Once again, however, there is some concern about the health effects of radar on children and other occupants. This concern is expressed in various reports available from the United States Food and Drug Administration Division of Devices. Naturally, electromagnetic waves from other parts of the electromagnetic spectrum could also be used such as, for example, those used with what are sometimes referred to as capacitive sensors, e.g., as described in U.S. patents by Kithil et al. U.S. Pat. Nos. 5,366,241, 5,602,734, 5,691,693, 5,802,479, 5,844,486 and 6,014,602 and by Jinno et al. U.S. Pat. No. 5,948,031 which are incorporated herein by reference.

The ultrasonic system is the least expensive and potentially provides less information than the optical or radar systems due to the delays resulting from the speed of sound and due to the wave length which is considerably longer than the optical (including infrared) systems. The wavelength limits the detail, which can be seen by the system. In spite of these limitations, as shown below, ultrasonics can provide sufficient timely information to permit the position and velocity of an occupant to be accurately known and, when used with an appropriate pattern recognition system, it is capable of positively determining the presence of a rear facing child seat. One pattern recognition system which has been used to identify a rear facing child seat uses neural networks and is similar to that described in the above-referenced papers by Gorman et al.

A focusing system, such as used on some camera systems, could be used to determine the initial position of an occupant but is too slow to monitor his position during a crash. This is a result of the mechanical motions required to operate the lens focusing system. By itself it cannot determine the presence of a rear facing child seat or of an occupant but when used with a charge-coupled device plus some infrared illumination for night vision, and an appropriate pattern recognition system, this becomes possible.

From the above discussion, it can be seen that the addition of sophisticated pattern recognition means to any of the standard illumination and/or reception technologies for use in a motor vehicle permits the development of a host of new products, systems or capabilities heretofore not available and as described in more detail below.

OBJECTS AND SUMMARY OF THE INVENTION

This invention includes a system to sense the presence, position and type of an occupying item such as a child seat in a passenger compartment of a motor vehicle and more particularly, to identify and monitor the occupying items and their parts and other objects in the passenger compartment of a motor vehicle, such as an automobile or truck, by processing one or more signals received from the occupying items and their parts and other objects using one or more of a variety of pattern recognition techniques and illumination technologies. The received signal(s) may be a reflection of a transmitted signal, the reflection of some natural signal within the vehicle, or may be some signal emitted naturally by the object. Information obtained by the identification and monitoring system is then used to affect the operation of some other system in the vehicle.

The invention also includes methods and arrangements for obtaining information about an object in a vehicle. This determination is used in various methods and arrangements for, e.g., controlling occupant protection devices in the event of a vehicle crash. The determination can also used in various methods and arrangements for, e.g., controlling heating and air-conditioning systems to optimize the comfort for any occupants, controlling an entertainment system as desired by the occupants, controlling a glare prevention device for the occupants, preventing accidents by a driver who is unable to safely drive the vehicle and enabling an effective and optimal response in the event of a crash (either oral directions to be communicated to the occupants or the dispatch of personnel to aid the occupants). Thus, one objective of the invention is to obtain information about occupancy of a vehicle and convey this information to remotely situated assistance personnel to optimize their response to a crash involving the vehicle and/or enable proper assistance to be rendered to the occupants after the crash.

Principle objects and advantages of the claimed invention are:

1. To recognize the presence of an object on a particular seat of a motor vehicle and to use this information to affect the operation of another vehicle system such as the entertainment system, airbag system, heating and air conditioning system, pedal adjustment system, mirror adjustment system, wireless data link system or cellular phone, among others.

2. To recognize the presence of an object on a particular seat of a motor vehicle and then to determine his/her position and to use this position information to affect the operation of another vehicle system.

3. To obtain information about an object in a vehicle using resonators or reflectors arranged in association with the object, such as the position of the object and the orientation of the object.

4. To provide a system designed to determine the orientation of a child seat using resonators or reflectors arranged in connection with the child seat.

5. To provide a system designed to determine whether a seatbelt is in use using resonators and reflectors, for possible use in the control of a safety device such as an airbag.

6. To provide a system designed to determine the position of an occupying item of a vehicle using resonators or reflectors, for possible use in the control of a safety device such as an airbag.

7. To provide a system designed to determine the position of a seat using resonators or reflectors, for possible use in the control of a vehicular component or system which would be affected by different seat positions.

In order to achieve objects of the invention, a control system for controlling an occupant restraint device effective for protection of an occupant of the seat comprises a receiving device arranged in the vehicle for obtaining information about contents of the seat and generating a signal based on any contents of the seat, a different signal being generated for different contents of the seat when such contents are present on the seat, an analysis unit such as a microprocessor coupled to the receiving device for analyzing the signal in order to determine whether the contents of the seat include a child seat, whether the contents of the seat include a child seat in a particular orientation and/or whether the contents of the seat include a child seat in a particular position, and a deployment unit coupled to the analysis unit for controlling deployment of the occupant restraint device based on the determination by the analysis unit.

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The analysis unit can be programmed to determine whether the contents of the seat include a child seat in a rear-facing position, in a forward-facing position, a rear-facing child seat in an improper orientation, a forward-facing child seat in an improper orientation, and the position of the child seat relative to one or more of the occupant restraint devices.

The receiving device can include a wave transmitter for transmitting waves toward the seat, a wave receiver arranged relative to the wave transmitter for receiving waves reflected from the seat and a processor coupled to the wave receiver for generating the different signal for the different contents of the seat based on the received waves reflected from the seat. The wave receiver can comprise multiple wave receivers spaced apart from one another with the processor being programmed to process the reflected waves from each receiver in order to create respective signals characteristic of the contents of the seat based on the reflected waves. In this case, the analysis unit preferably categorizes the signals using for example a pattern recognition algorithm for recognizing and thus identifying the contents of the seat by processing the signals based on the reflected waves from the contents of the seat into a categorization of the signals characteristic of the contents of the seat.

A system for obtaining information about an object in the vehicle comprises at least one resonator arranged in association with the object and which emits an energy signal upon receipt of a signal at an excitation frequency, a transmitter for transmitting signals at least at the excitation frequency of each resonator, an energy signal detector device for detecting the energy signal emitted by the resonator(s) upon receipt of the signal at the excitation frequency and a processor coupled to the detector device for obtaining information about the object upon analysis of the energy signal detected by the detector device. The information obtained about the object may be a distance between each resonator and the detector device or an indication of the position of the seat.

The resonator may comprise a tuned resonator including an acoustic cavity or a vibrating mechanical element. When multiple resonators are used, each resonator is preferably designed to emit an energy signal upon receipt of a signal at a different excitation frequency.

If the object is a seatbelt, the information obtained about the seatbelt may be an indication of whether the seatbelt is in use and/or an indication of the position of the seatbelt.

If the object is a child seat, the information obtained about the child seat may be an indication of the orientation of the child seat and/or an indication of the position of the child seat.

If the object is a window of the vehicle, the information obtained about the window may be an indication of whether the window is open or closed.

If the object is a door, the resonator is arranged in a surface facing the door such that closure of the door prevents emission of the energy signal therefrom, in which case, the information obtained about the door is an indication of whether the door is open or closed.

Principle objects and advantages of other disclosed inventions that can be used in conjunction with the claimed invention are:

1. To determine the presence of a child in a child seat based on motion of the child.

2. To determine the presence of a life form anywhere in a vehicle based on motion of the life form.

3. To provide a security system for a vehicle which determines the presence of an unexpected life form in a vehicle and conveys the determination prior to entry of a driver into the vehicle.

4. To provide an occupant sensing system which detects the presence of a life form in a vehicle and under certain conditions, activates a vehicular warning system or a vehicular system to prevent injury to the life form

5. To provide a system using radar which detects a heartbeat of life forms in a vehicle.

6. To provide a system using electromagnetics or ultrasonics to detect motion of objects in a vehicle and enable the use of the detection of the motion for control of vehicular components and systems.

7. To affect the vehicle entertainment system, e.g., the speakers, based on a determination of the number, size and/or location of various occupants or other objects within the vehicle passenger compartment.

8. To determine the location of the ears of one or more vehicle occupants and to use that information to control the entertainment system, e.g., the speakers, so as to improve the quality of the sound reaching the occupants' ears through such methods as noise canceling sound.

9. To recognize the presence of a human on a particular seat of a motor vehicle and then to determine his/her velocity relative to the passenger compartment and to use this velocity information to affect the operation of another vehicle system.

10. To determine the position of a seat in the vehicle using sensors remote from the seat and to use that information in conjunction with a memory system and appropriate actuators to position the seat to a predetermined location.

11. To determine the position, velocity or size of an occupant in a motor vehicle and to utilize this information to control the rate of gas generation, or the amount of gas generated, by an airbag inflator system or otherwise control the flow of gas into or out of an airbag.

12. To determine the fact that an occupant is not restrained by a seatbelt and therefore to modify the characteristics of the airbag system. This determination can be done either by monitoring the position of the occupant or through the use of a resonating device placed on the shoulder belt portion of the seatbelt.

13. To determine the presence and/or position of rear seated occupants in the vehicle and to use this information to affect the operation of a rear seat protection airbag for frontal impacts.

14. To determine the presence and/or position of occupants relative to the side impact airbag systems and to use this information to affect the operation of a side impact protection airbag system.

15. To determine the openness of a vehicle window and to use that information to affect another vehicle system.

16. To determine the presence of an occupant's hand or other object in the path of a closing window and to affect the window closing system.

17. To remotely determine the fact that a vehicle door is not tightly closed using an illumination transmitting and receiving system such as one employing electromagnetic or acoustic waves.

18. To determine the position of the shoulder of a vehicle occupant and to use that information to control the seatbelt anchorage point.

19. To determine the position of the rear of an occupant's head and to use that information to control the position of the headrest.

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20. To recognize the presence of a rear facing child seat on a particular seat of a motor vehicle and to use this information to affect the operation of another vehicle system such as the airbag system.

21. To determine the total number of occupants of a vehicle and in the event of an accident to transmit that information, as well as other information such as the condition of the occupants, to a receiver remote from the vehicle.

22. To affect the vehicle heating, ventilation and air conditioning system based on a determination of the number, size and location of various occupants or other objects within the vehicle passenger compartment.

23. To determine the temperature of an occupant based on infrared radiation coming from that occupant and to use that information to control the heating, ventilation and air conditioning system.

24. To provide a vehicle interior monitoring system for determining the location of occupants within the vehicle and to include within the same system various electronics for controlling an airbag system.

25. To determine the approximate location of the eyes of a driver and to use that information to control the position of the rear view mirrors of the vehicle.

26. To monitor the position of the head of the vehicle driver and determine whether the driver is falling asleep or otherwise impaired and likely to lose control of the vehicle and to use that information to affect another vehicle system.

27. To monitor the position of the eyelids of the vehicle driver and determine whether the driver is falling asleep or otherwise impaired and likely to lose control of the vehicle, or is unconscious after an accident, and to use that information to affect another vehicle system.

28. To determine the location of the eyes of a vehicle occupant and the direction of a light source such as the headlights of an oncoming vehicle or the sun and to cause a filter to be placed in such a manner as to reduce the intensity of the light striking the eyes of the occupant.

29. To determine the location of the eyes of a vehicle occupant and the direction of a light source such as the headlights of a rear approaching vehicle or the sun and to cause a filter to be placed in such a manner as to reduce the intensity of the light reflected from the rear view mirrors and striking the eyes of the occupant.

30. To recognize a particular driver based on such factors as physical appearance or other attributes and to use this information to control another vehicle system such as a security system, seat adjustment, or maximum permitted vehicle velocity, among others.

31. To provide an occupant sensor which determines the presence and health state of any occupants in a vehicle. The presence of the occupants may be determined using an animal life or heart beat sensor.

32. To provide an occupant sensor which determines whether any occupants of the vehicle are breathing by analyzing the occupant's motion. It can also be determined whether an occupant is breathing with difficulty.

33. To provide an occupant sensor which determines whether any occupants of the vehicle are breathing by analyzing the chemical composition of the air/gas in the vehicle, e.g., in proximity of the occupant's mouth.

34. To provide an occupant sensor which determines whether any occupants of the vehicle are conscious by analyzing movement of their eyes.

35. To provide an occupant sensor which determines whether any occupants of the vehicle are wounded to the extent that they are bleeding by analyzing air/gas in the vehicle, e.g., directly around each occupant.

36. To provide an occupant sensor which determines the presence and health state of any occupants in the vehicle by analyzing sounds emanating from the passenger compartment. Such sounds can be directed to a remote, manned site for consideration in dispatching response personnel.

37. To provide an occupant sensor which determines whether any occupants of the vehicle are moving using radar systems, e.g., micropower impulse radar (MIR), which can also detect the heartbeats of any occupants.

38. To provide a vehicle monitoring system which provides a communications channel between the vehicle (possibly through microphones distributed throughout the vehicle) and a manned assistance facility to enable communications with the occupants after a crash or whenever the occupants are in need of assistance (e.g., if the occupants are lost, then data forming maps as a navigational aid would be transmitted to the vehicle).

BRIEF DESCRIPTION OF THE DRAWINGS

The following drawings are illustrative of embodiments of the system developed or adapted using the teachings of this invention and are not meant to limit the scope of the invention as encompassed by the claims.

FIG. **1** is a side view with parts cutaway and removed of a vehicle showing the passenger compartment containing a rear facing child seat on the front passenger seat and a preferred mounting location for an occupant and rear facing child seat presence detector.

FIG. **1A** is a side view with parts cutaway and removed of a vehicle showing the passenger compartment containing a rear facing child seat on the front passenger seat having a resonator or reflector placed onto the forward most portion of the child seat.

FIG. **2** is a side view with parts cutaway and removed showing schematically the interface between the vehicle interior monitoring system of this invention and the vehicle cellular communication system.

FIG. **2A** is a diagram of one exemplifying embodiment of the invention.

FIG. **3** is a side view with parts cutaway and removed showing schematically the interface between the vehicle interior monitoring system of this invention and the vehicle heating and air conditioning system.

FIG. **4** is a side view with parts cutaway and removed showing schematically the interface between the vehicle interior monitoring system of this invention and the vehicle airbag system.

FIG. **5** is a side view with parts cutaway and removed showing schematically the interface between the vehicle interior monitoring system of this invention and the vehicle entertainment system.

FIG. **5A** is a schematic representation of a vehicle in which the entertainment system utilizes hypersonic sound.

FIG. **6** is a side view with parts cutaway and removed of a vehicle showing the passenger compartment containing a driver and a preferred mounting location for an occupant identification system.

FIG. **7A** is a functional block diagram of the ultrasonic imaging system illustrated in FIG. **1** using a microprocessor.

FIG. **7B** is a functional block diagram of the ultrasonic imaging system illustrated in FIG. **1** using an application specific integrated circuit (ASIC).

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FIG. **8** is a side view with parts cutaway and removed of a vehicle showing the passenger compartment containing a box on the front passenger seat and a preferred mounting location for an occupant and rear facing child seat presence detector.

FIG. **9** is a side view with parts cutaway and removed of a vehicle showing the passenger compartment containing a driver and a preferred mounting location for an occupant position sensor for use in side impacts and also of a rear of occupant's head locator for use with a headrest adjustment system to reduce whiplash injuries in rear impact crashes.

FIG. **10** is a side view with parts cutaway and removed of a vehicle showing the passenger compartment containing a front passenger and a preferred mounting location for an occupant head detector and a preferred mounting location of an adjustable microphone and speakers.

FIG. **11** is a side view with parts cutaway and removed of a subject vehicle and an oncoming vehicle, showing the headlights of the oncoming vehicle and the passenger compartment of the subject vehicle, containing detectors of the driver's eyes and detectors for the headlights of the oncoming vehicle and the selective filtering of the light of the approaching vehicle's headlights through the use of electrochromic glass in the windshield.

FIG. **11A** is an enlarged view of the section **11A** in FIG. **11**.

FIG. **12** is a side view with parts cutaway and removed of a vehicle and a following vehicle showing the headlights of the following vehicle and the passenger compartment of the leading vehicle containing a driver and a preferred mounting location for driver eyes and following vehicle headlight detectors and the selective filtering of the light of the following vehicle's headlights through the use of electrochromic glass in the rear view mirror.

FIG. **12A** is an enlarged view of the section designated **12A** in FIG. **12**.

FIG. **12B** is an enlarged view of the section designated **12B** in FIG. **12A**.

FIG. **13** is a side view with parts cutaway and removed of a vehicle showing the passenger compartment containing a driver, a shoulder height sensor and a seatbelt anchorage adjustment system.

FIG. **14** is a side view with parts cutaway and removed of a seat in the passenger compartment of a vehicle showing the use of ultrasonic resonators or reflectors to determine the position of the seat.

FIG. **15** is a side view with parts cutaway and removed of the passenger compartment of a vehicle showing the use of ultrasonic resonators or reflectors to determine the position of the driver seatbelt.

FIG. **16** is a side view with parts cutaway and removed of the passenger compartment of a vehicle showing the use of an ultrasonic resonator or reflector to determine the extent of opening of the driver window and of a system for determining the presence of an object, such as the hand of an occupant, in the window opening.

FIG. **16A** is a side view with parts cutaway and removed of the passenger compartment of a vehicle showing the use of an ultrasonic resonator or reflectors to determine the extent of opening of the driver window and of another system for determining the presence of an object, such as the hand of an occupant, in the window opening.

FIG. **17** is a side view with parts cutaway and removed of the passenger compartment of a vehicle showing the use of an ultrasonic resonator or reflectors to determine the extent of opening of the driver side door.

FIG. **18** is a side view with parts cutaway and removed showing schematically the interface between the vehicle interior monitoring system of this invention and the vehicle security system.

FIG. **19** is a side view with parts cutaway and removed showing schematically the interface between the vehicle interior monitoring system of this invention and an instrument panel mounted inattentiveness warning light or buzzer and reset button.

FIG. **20** is a side view, with certain portions removed or cut away, of a portion of the passenger compartment of a vehicle showing several preferred mounting locations of occupant position sensors for sensing the position of the vehicle driver.

FIG. **21** is a cross section view of a steering wheel and airbag module assembly showing a preferred mounting location of an ultrasonic wave generator and receiver.

FIG. **22** is a side view, with certain portions removed or cut away, of a portion of the passenger compartment of a vehicle showing preferred mounting locations of the occupant position sensor employing multiple transmitters and receivers.

FIG. **23** is a side view, with certain portions removed or cut away, of a portion of the passenger compartment of a vehicle showing an occupant position sensor used in combination with a reflective windshield for sensing the position of the vehicle passenger.

FIG. **24** is a partial cutaway view of a seatbelt retractor with a spool out sensor utilizing a shaft encoder.

FIG. **25** is a side view of a portion of a seat and seat rail showing a seat position sensor utilizing a potentiometer.

FIG. **26** is a circuit schematic illustrating the use of the occupant position sensor in conjunction with the remainder of the inflatable restraint system.

FIG. **27** is a schematic illustrating the circuit of an occupant position-sensing device using a modulated infrared signal, beat frequency and phase detector system.

FIG. **28** is a schematic drawing of one embodiment of an occupant restraint device control system in accordance with the invention.

FIG. **29** is a flow chart of the operation of one embodiment of an occupant restraint device control method in accordance with the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the accompanying drawings wherein the same reference numerals refer to the same or similar elements, FIG. **1** is a side view, with parts cutaway and removed of a vehicle showing the passenger compartment containing a rear facing child seat **110** on a front passenger seat **120** and a preferred mounting location for a first embodiment of a vehicle interior monitoring system in accordance with the invention. The interior monitoring system is capable of detecting the presence of an occupant and the rear facing child seat **110**. In this embodiment, three transducers **131**, **132** and **133** are used, although any number of wave-transmitting transducers or radiation-receiving receivers may be used. Such transducers or receivers may be of the type which emit or receive a continuous signal, a time varying signal or a spacial varying signal such as in a scanning system. One particular type of radiation-receiving receiver for use in the invention is a receiver capable of receiving electromagnetic waves. In an embodiment wherein ultrasonic energy is used, transducer **132** transmits

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ultrasonic energy toward the front passenger seat, which is modified, in this case by the occupying item of the passenger seat, i.e., the rear facing child seat **110**, and the modified waves are received by the transducers **131** and **133**. Modification of the ultrasonic energy may constitute reflection of the ultrasonic energy as the ultrasonic energy is reflected back by the occupying item of the seat. The waves received by transducers **131** and **133** vary with time depending on the shape of the object occupying the passenger seat, in this case the rear facing child seat **110**. Each object will reflect back waves having a different pattern. Also, the pattern of waves received by transducer **131** will differ slightly from the pattern received by transducer **133** in view of its different mounting location. In some systems, this difference permits the determination of location of the reflecting surface (i.e., the rear facing child seat **110**) through triangulation. Through the use of two transducers **131,133**, a sort of stereographic image is received by the two transducers and recorded for analysis by processor **101**, which is coupled to the transducers **131,132,133**. This image will differ for each object that is placed on the vehicle seat and it will also change for each position of a particular object and for each position of the vehicle seat. Elements **131,132,133**, although described as transducers, are representative of any type of component used in a wave-based analysis technique, including, e.g., a transmitter and a capacitor plate.

The "image" recorded from each ultrasonic transducer/receiver, for ultrasonic systems, is actually a time series of digitized data of the amplitude of the received signal versus time. Since there are two receivers, two time series are obtained which are processed by the processor **101**. The processor **101** may include electronic circuitry and associated, embedded software. Processor **101** constitutes one form of generating means in accordance with the invention which generates information about the occupancy of the passenger compartment based on the waves received by the transducers **131,132,133**.

When different objects are placed on the front passenger seat, the two images from transducers **131,133** are different but there are also similarities between all images of rear facing child seats, for example, regardless of where on the vehicle seat it is placed and regardless of what company manufactured the child seat. Alternately, there will be similarities between all images of people sitting on the seat regardless of what they are wearing, their age or size. The problem is to find the "rules" which differentiate the images of one type of object from the images of other types of objects, e.g., which differentiate the occupant images from the rear facing child seat images. The similarities of these images for various child seats are frequently not obvious to a person looking at plots of the time series and thus computer algorithms are developed to sort out the various patterns. For a more detailed discussion of pattern recognition see U.S. Pat. No. 5,943,295 to Varga et. al., which is incorporated herein by reference.

The determination of these rules is central to the pattern recognition techniques used in this invention. In general, three approaches have been useful, artificial intelligence, fuzzy logic and artificial neural networks (although additional types of pattern recognition techniques may also be used, such as sensor fusion). In some implementations of this invention, such as the determination that there is an object in the path of a closing window as described below, the rules are sufficiently obvious that a trained researcher can look at the returned acoustic signals and devise a simple algorithm to make the required determinations. In others, such as the determination of the presence of a rear facing child seat or of an occupant, artificial neural networks are used to determine the rules. One such set of neural network software for determining the pattern recognition rules is available from the NeuralWare Corporation of Pittsburgh, Pa.

The system used in a preferred implementation of this invention for the determination of the presence of a rear facing child seat, of an occupant or of an empty seat is the artificial neural network. In this case, the network operates on the two returned signals as sensed by transducers **131** and **133**. Through a training session, the system is taught to differentiate between the three cases. This is done by conducting a large number of experiments where all possible child seats are placed in all possible orientations on the front passenger seat. Similarly, a sufficiently large number of experiments are run with human occupants and with boxes, bags of groceries and other objects (both inanimate and animate). Sometimes as many as 1,000,000 such experiments are run before the neural network is sufficiently trained so that it can differentiate among the three cases and output the correct decision with a very high probability. Of course, it must be realized that a neural network can also be trained to differentiate among additional cases, e.g., a forward facing child seat.

Once the network is determined, it is possible to examine the result using tools supplied by NeuralWare, for example, to determine the rules that were finally arrived at by the trial and error techniques. In that case, the rules can then be programmed into a microprocessor resulting in a fuzzy logic or other rule based system. Alternately, a neural computer can be used to implement the net directly. In either case, the implementation can be carried out by those skilled in the art of pattern recognition. If a microprocessor is used, a memory device is also required to store the data from the analog to digital converters that digitize the data from the receiving transducers. On the other hand, if a neural network computer is used, the analog signal can be fed directly from the transducers to the neural network input nodes and an intermediate memory is not required. Memory of some type is needed to store the computer programs in the case of the microprocessor system and if the neural computer is used for more than one task, a memory is needed to store the network specific values associated with each task.

In the embodiment wherein electromagnetic energy is used, it is to be appreciated that any portion of the electromagnetic signals that impinges upon a body portion of the occupant is at least partially absorbed by the body portion. Sometimes, this is due to the facts that the human body is composed primarily of water, and that electromagnetic energy is readily absorbed by water. The amount of electromagnetic signal absorption is related to the frequency of the signal, and size or bulk of the body portion that the signal impinges upon. For example, a torso of a human body tends to absorb a greater percentage of electromagnetic energy as compared to a hand of a human body for some frequencies.

Thus, when electromagnetic waves or energy signals are transmitted by a transmitter, the returning waves received by a receiver provide an indication of the absorption of the electromagnetic energy. That is, absorption of electromagnetic energy will vary depending on the presence or absence of a human occupant, the occupant's size, bulk, etc., so that different signals will be received relating to the degree or extent of absorption by the occupying item on the seat. The receiver will produce a signal representative of the returned waves or energy signals which will thus constitute an absorption signal as it corresponds to the absorption of electromagnetic energy by the occupying item in the seat.

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An alternate system is shown in FIG. **2**, which is a side view showing schematically the interface between the vehicle interior monitoring system of this invention and the vehicle cellular communication system. In this view, an adult occupant **210** is shown sitting on the front passenger seat **220** and two transducers **231** and **232** are used to determine the presence (or absence) of the occupant on that seat **220**. One of the transducers **232** in this case acts as both a transmitter and receiver while transducer **231** acts only as a receiver. Alternately, transducer **231** could serve as both a transmitter and receiver or the transmitting function could be alternated between the two devices. Also, in many cases more that two transmitters and receivers are used and in still other cases other types of sensors, such as weight, seatbelt, heartbeat, motion and seat position sensors, are also used in combination with the radiation sensors. As was also the case in FIG. **1**, the transducers **231** and **232** are attached to the vehicle buried in the A-pillar trim, where their presence is disguised, and are connected to processor **101** that may also hidden in the trim as shown (this being a non-limiting position for the processor **101**). The A-pillar is the roof support pillar that is closest to the front of the vehicle and which, in addition to supporting the roof, also supports the front windshield and the front door. Naturally, other mounting locations can also be used.

The interface between the monitoring system and the cellular phone system is shown schematically by box **240** that outputs to an antenna **250**A. The transducers **231** and **232** in conjunction with the pattern recognition hardware and software, which is implemented in processor **101** and is packaged on a printed circuit board or flex circuit along with the transducers **231** and **232**, determine the presence of an occupant within a few seconds after the vehicle is started. Similar systems located to monitor the remaining seats in the vehicle, also determine the presence of occupants at the other seating locations and this result is stored in the computer memory which is part of each monitoring system processor **101**. In the event of an accident, the electronic system associated with the cellular phone system interrogates the various interior monitoring system memories and arrives at a count of the number of occupants in the vehicle, and in more sophisticated systems, even makes a determination as to whether each occupant was wearing a seatbelt and if he or she is moving after the accident. The phone system then automatically dials the EMS operator (such as 911) and the information obtained from the interior monitoring systems is forwarded so that a determination can be made as to the number of ambulances and other equipment to send to the accident site, Vehicles having this capability are now in service but are not believed to use any of the innovative interior monitoring systems described herein. Such vehicles will also have a system, such as the global positioning system, which permits the vehicle to determine its exact location and to forward this information to the EMS operator.

Thus, in basic embodiments of the invention, wave or energy-receiving transducers are arranged in the vehicle at appropriate locations, trained if necessary depending on the particular embodiment, and function to determine whether a life form is present in the vehicle and if so, how many life forms are present. A determination can also be made using the transducers as to whether the life forms are humans, or more specifically, adults, child in child seas, etc. As noted above and below, this is possible using pattern recognition techniques. Moreover, the processor or processors associated with the transducers can be trained to determine the location of the life forms, either periodically or continuously or possibly only immediately before, during and after a crash. The location of the life forms can be as general or as specific as necessary depending on the system requirements, i.e., a determination can be made that a human is situated on the driver's seat in a normal position (general) or a determination can be made that a human is situated on the driver's seat and is leaning forward and/or to the side at a specific angle as well as the position of his or her extremities and head and chest (specific). The degree of detail is limited by several factors, including, e.g., the number and position of transducers and training of the pattern recognition algorithm.

In addition to the use of transducers to determine the presence and location of occupants in a vehicle, other sensors could also be used. For example, a heartbeat sensor which determines the number and presence of heartbeats can also be arranged in the vehicle. Conventional heartbeat sensors can be adapted to differentiate between a heartbeat of an adult, a heartbeat of a child and a heartbeat of an animal. As its name implies, a heartbeat sensor detects a heartbeat, and the magnitude thereof, of a human occupant of the seat, if such a human occupant is present. The output of the heartbeat sensor is input to the processor of the interior monitoring system. One heartbeat sensor for use in the invention may be of the types as disclosed in McEwan (U.S. Pat. Nos. 5,573,012 and 5,766,208 which are incorporated herein in their entirety by reference). The heartbeat sensor can be positioned at any convenient position relative to the seats where occupancy is being monitored. A preferred location is within the vehicle seatback.

Another type of sensor which is not believed to have been used in an interior monitoring system heretofore is a micropower impulse radar (MIR) sensor which determines motion of an occupant and thus can determine his or her heartbeat (as evidenced by motion of the chest). Such an MIR sensor could be arranged to detect motion in a particular area in which the occupant's chest would most likely be situated or could be coupled to an arrangement which determines the location of the occupant's chest and then adjusts the operational field of the MIR sensor based on the determined location of the occupant's chest. A motion sensor utilizing a micro-power impulse radar (MIR) system as disclosed, for example, in McEwan (U.S. Pat. No. 5,361,070, which is incorporated herein by reference), as well as many other patents by the same inventor. Motion sensing is accomplished by monitoring a particular range from the sensor as disclosed in that patent. MIR is one form of radar which has applicability to occupant sensing and can be mounted at various locations in the vehicle. It has an advantage over ultrasonic sensors in that data can be acquired at a higher speed and thus the motion of an occupant can be more easily tracked. The ability to obtain returns over the entire occupancy range is somewhat more difficult than with ultrasound resulting in a more expensive system overall. MIR has additional advantages in lack of sensitivity to temperature variation and has a comparable resolution to about 40 kHz ultrasound. Resolution comparable to higher frequency is feasible but has not been demonstrated. Additionally, multiple MIR sensors can be used when high speed tracking of the motion of an occupant during a crash is required since they can be individually pulsed without interfering with each through time division multiplexing.

An alternative way to determine motion of the occupant(s) would be to monitor the weight distribution of the occupant whereby changes in weight distribution after an accident would be highly suggestive of movement of the

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occupant. A system for determining the weight distribution of the occupants could be integrated or otherwise arranged in the seats **120,220** of the vehicle and several patents and publications describe such systems.

More generally, any sensor which determines the presence and health state of an occupant could also be integrated into the vehicle interior monitoring system in accordance with the invention. For example, a sensitive motion sensor can determine whether an occupant is breathing and a chemical sensor can determine the amount of carbon dioxide, or the concentration of carbon dioxide, in the air in the vehicle which can be correlated to the health state of the occupant(s). The motion sensor and chemical sensor can be designed to have a fixed operational field situated where the occupant's mouth is most likely to be located. In the alternative, the motion sensor and chemical sensor can be adjustable and adapted to adjust their operational field in conjunction with a determination by an occupant position and location sensor which would determine the location of specific parts of the occupant's body, e.g., his or her chest or mouth. Furthermore, an occupant position and location sensor can be used to determine the location of the occupant's eyes and determine whether the occupant is conscious, i.e., whether his or her eyes are open or closed or moving.

The use of chemical sensors could also conceivably be used to detect whether there is blood present in the vehicle, e.g., after an accident. Additionally, microphones can detect whether there is noise in the vehicle caused by groaning, yelling, etc., and transmit any such noise through the cellular connection to a remote listening facility (such as operated by OnStar™).

FIG. 2A shows a schematic diagram of an embodiment of the invention including a system for determining the presence and health state of any occupants of the vehicle and a telecommunications link. This embodiment includes means for determining the presence of any occupants **10** which may take the form of a heartbeat sensor or motion sensor as described above and means for determining the health state of any occupants **12**. The latter means may be integrated into the means for determining the presence of any occupants, i.e., one and the same component, or separate therefrom. Further, means for determining the location, and optionally velocity, of the occupants or one or more parts thereof **14** are provided and may be any conventional occupant position sensor or preferably, one of the occupant position sensors as described herein (e.g., those utilizing waves or electromagnetic radiation) or as described in the current assignee's patents and patent applications referenced A processor **16** is coupled to the presence determining means **10**, the health state determining means **12** and the location determining means **14**. A communications unit **18** is coupled to the processor **16**. The processor **16** and/or communications unit **18** can also be coupled to microphones **20** distributed throughout the vehicle and include voice-processing circuitry to enable the occupant(s) to effect vocal control of the processor **16**, communications unit **18** or any coupled component or oral communications via the communications unit **18**. The processor **16** is also coupled to another vehicular system, component or subsystem **22** and can issue control commands to effect adjustment of the operating conditions of the system, component or subsystem. Such a system, component or subsystem can be the heating or air-conditioning system, the entertainment system, an occupant restraint device such as an airbag, a glare prevention system, etc. Also, a positioning system **24** could be coupled to the processor **16** and provides an indication of the absolute position of the vehicle, preferably using satellite-based positioning technology (e.g., a GPS receiver).

In normal use (other than after a crash), the presence determining means **10** determine whether any human occupants are present, i.e., adults or children, and the location determining means **14** determine the occupant's location. The processor **16** receives signals representative of the presence of occupants and their location and determines whether the vehicular system, component or subsystem **22** can be modified to optimize its operation for the specific arrangement of occupants. For example, if the processor **16** determines that only the front seats in the vehicle are occupied, it could control the heating system to provide heat only through vents situated to provide heat for the front-seated occupants.

Another possible vehicular system, component or subsystem is a navigational aid, i.e., a route display or map. In this case, the position of the vehicle as determined by the positioning system **24** is conveyed through processor **16** to the communications unit **18** to a remote facility and a map is transmitted from this facility to the vehicle to be displayed on the route display. If directions are needed, a request for the same could be entered into an input unit **26** associated with the processor **16** and transmitted to the facility. Data for the display map and/or vocal instructions could be transmitted from this facility to the vehicle.

Moreover, using this embodiment, it is possible to remotely monitor the health state of the occupants in the vehicle and most importantly, the driver. The health state determining means **12** may be used to detect whether the driver's breathing is erratic or indicative of a state in which the driver is dozing off. The health state determining means **12** could also include a breath-analyzer to determine whether the driver's breath contains alcohol. In this case, the health state of the driver is relayed through the processor **16** and the communications unit **18** to the remote facility and appropriate action can be taken. For example, it would be possible to transmit a command to the vehicle to activate an alarm or illuminate a warning light or if the vehicle is equipped with an automatic guidance system and ignition shut-off, to cause the vehicle to come to a stop on the shoulder of the roadway or elsewhere out of the traffic stream. The alarm, warning light, automatic guidance system and ignition shut-off are thus particular vehicular components or subsystems represented by **22**.

In use after a crash, the presence determining means **10**, health state determining means **12** and location determining means **14** obtain readings from the passenger compartment and direct such readings to the processor **16**. The processor **16** analyzes the information and directs or controls the transmission of the information about the occupant(s) to a remote, manned facility. Such information would include the number and type of occupants, i.e., adults, children, infants, whether any of the occupants have stopped breathing or are breathing erratically, whether the occupants are conscious (as evidenced by, e.g., eye motion), whether blood is present (as detected by a chemical sensor) and whether the occupants are making noise. Moreover, the communications link through the communications unit **18** can be activated immediately after the crash to enable personnel at the remote facility to initiate communications with the vehicle.

The control of the heating, ventilating, and air conditioning (HVAC) system alone would probably not justify the implementation of an interior monitoring system at least until the time comes when electronic heating and cooling systems replace the conventional systems now used.

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Nevertheless, if the monitoring system is present, it can be used to control the HVAC for a small increment in cost. The advantage of such a system is that since most vehicles contain only a single occupant, there is no need to direct heat or air conditioning to unoccupied seats. This permits the most rapid heating or cooling for the driver when the vehicle is first started and he is alone without heating or cooling unoccupied seats. Since the HVAC system does consume energy, an energy saving also results by only heating and cooling the driver when he is alone.

FIG. **3** shows a side view of a vehicle passenger compartment showing schematically an interface **260** between the vehicle interior monitoring system of this invention and the vehicle heating and air conditioning system. In addition to the transducers **231** and **232**, which at least in this embodiment are preferably acoustic transducers, an infrared sensor **234** is also shown mounted in the A-pillar and is constructed and operated to monitor the temperature of the occupant. The output from each of the transducers is fed into processor **101** that is in turn connected to interface **260**. In this manner, the HVAC control is based on the occupant's temperature rather than that of the ambient air in the vehicle, as well as the determined presence of the occupant via transducers **231,232** as described above. This also permits each vehicle occupant to be independently monitored and the HVAC system to be adjusted for each occupant either based on a set temperature for all occupants or, alternately, each occupant could be permitted to set his own preferred temperature through adjusting a control knob shown schematically as **250** in FIG. **3**. Since the monitoring system is already installed in the vehicle with its own associated electronics including processor **101**, the infrared sensor can be added with little additional cost and can share the processing unit.

Not only can this system be used for directing hot and cold air, but developments in the field of directing sound using hyper-sound (also referred to as hypersonic sound) now make it possible to accurately direct sound to the vicinity of the ears of an occupant so that only that occupant can hear the sound. The system of this invention can thus be used to find the proximate direction of the ears of the occupant for this purpose. Additional discussion of this aspect is set forth below with respect to FIG. **5A**.

Hypersonic sound is described in detail in U.S. Pat. Nos. 5,885,129 (Norris), U.S. Pat. No. 5,889,870 (Norris) and U.S. Pat. No. 6,016,351 (Raida et al.) and International Publication No. WO 00/18031 which are incorporated by reference herein in their entirety to the extent the disclosure of these references is necessary. By practicing the techniques described in these patents and the publication, in some cases coupled with a mechanical or acoustical steering mechanism, sound can be directed to the location of the ears of a particular vehicle occupant in such a manner that the other occupants can barely hear the sound, if at all. This is particularly the case when the vehicle is operating at high speeds on the highway and a high level of "white" noise is present. In this manner, one occupant can be listening to the news while another is listening to an opera, for example. Naturally, white noise can also be added to the vehicle and generated by the hypersonic sound system if necessary when the vehicle is stopped or traveling in heavy traffic. Thus, several occupants of a vehicle can listen to different programming without the other occupants hearing that programming. This can be accomplished using hypersonic sound without requiring earphones.

In principle, hypersonic sound utilizes the emission of inaudible ultrasonic frequencies that mix in air and result in the generation of new audio frequencies. A hypersonic sound system is a highly efficient converter of electrical energy to acoustical energy. Sound is created in air at any desired point which provides flexibility and allows manipulation of the perceived location of the source of the sound. Speaker enclosures are thus rendered dispensable. The dispersion of the mixing area of the ultrasonic frequencies and thus the area in which the new audio frequencies are audible can be controlled to provide a very narrow or wide area as desired.

The audio mixing area generated by each set of two ultrasonic frequency generators in accordance with the invention could thus be directly in front of the ultrasonic frequency generators in which case the audio frequencies would travel from the mixing area in a narrow straight beam or cone to the occupant. Also, the mixing area could include only a single ear of an occupant (another mixing area being formed by ultrasonic frequencies generated by a set of two other ultrasonic frequency generators at the location of the other ear of the occupant with presumably but not definitely the same new audio frequencies) or be large enough to encompass the head and both ears of the occupant. If so desired, the mixing area could even be controlled to encompass the determined location of the cars of multiple occupants, e.g., occupants seated one behind the other or one next to another.

The use of the vehicle interior monitoring system to control the deployment of an airbag is discussed in detail in U.S. Pat. No. 5,653,462 referenced above. In that case, the control is based on the use of a simple pattern recognition system to differentiate between the occupant and his extremities in order to provide an accurate determination of the position of the occupant relative to the airbag. If the occupant is sufficiently close to the airbag module that he is more likely to be injured by the deployment itself than by the accident, the deployment of the airbag is suppressed. This process is carried further by the interior monitoring system described herein in that the nature or identity of the object occupying the vehicle seat is used to contribute to the airbag deployment decision. FIG. **4** shows a side view illustrating schematically the interface between the vehicle interior monitoring system of this invention and the vehicle airbag system **270**.

In this embodiment, an ultrasonic transducer **232** transmits a burst of ultrasonic waves that travel to the occupant where they are reflected back to transducers or receptors/receivers **231** and **232**. The time period required for the waves to travel from the generator and return is used to determine the distance from the occupant to the airbag as described in the aforementioned U.S. Pat. No. 5,653,462, i.e., and thus may also be used to determine the position or location of the occupant. In the case of this invention, however, the portion of the return signal, which represents the occupants' head or chest, has been determined based on pattern recognition techniques such as a neural network. The relative velocity of the occupant toward the airbag can then be determined, from successive position measurements, which permits a sufficiently accurate prediction of the time when the occupant would become proximate to the airbag. By comparing the occupant relative velocity to the integral of the crash deceleration pulse, a determination as to whether the occupant is being restrained by a seatbelt can also be made which then can affect the airbag deployment initiation decision. Alternately, the mere knowledge that the occupant has moved a distance which would not be possible if he were wearing a seatbelt gives information that he is not wearing one.

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A more detailed discussion of this process and of the advantages of the various technologies, such as acoustic or electromagnetic, can be found in SAE paper 0.940527, "Vehicle Occupant Position Sensing" by Breed et al, which is incorporated herein by reference in its entirety to the extent the disclosure of this paper is necessary. In this paper, it is demonstrated that the time delay required for acoustic waves to travel to the occupant and return does not prevent the use of acoustics for position measurement of occupants during the crash event. For position measurement and for many pattern recognition applications, ultrasonics is the preferred technology due to the lack of adverse health effects and the low cost of ultrasonic systems compared with either laser or radar. The main limiting feature of ultrasonics is the wavelength, which places a limitation on the size of features that can be discerned. Optical systems, for example, are required when the identification of particular individuals is required.

It is well known among acoustics engineers that the quality of sound coming from an entertainment system can be substantially affected by the characteristics and contents of the space in which it operates and the surfaces surrounding that space. When an engineer is designing a system for an automobile he has a great deal of knowledge about that space and of the vehicle surfaces surrounding it. He has little knowledge of how many occupants are likely to be in the vehicle on a particular day, however, and therefore the system is a compromise. If the system knew the number and position of the vehicle occupants, and maybe even their size, then adjustments could be made in the system output and the sound quality improved. FIG. **5**, therefore, illustrates schematically the interface between the vehicle interior monitoring system of this invention, i.e., transducers **231,232** and processor **101** which operate as set forth above, and the vehicle entertainment system **280**. The particular design of the entertainment system that uses the information provided by the monitoring system can be determined by those skilled in the appropriate art. Perhaps in combination with this system, the quality of the sound system can be measured by the audio system itself either by using the speakers as receiving units also or through the use of special microphones. The quality of the sound can then be adjusted according to the vehicle occupancy and the reflectivity of the vehicle occupants. If, for example, certain frequencies are being reflected more that others, the audio amplifier can be adjusted to amplify those frequencies to a lesser amount that others.

Vehicle entertainment system **280** may include means for generating and transmitting sound waves at the ears of the occupants, the position of which are detected by transducers **231,232** and processor **101**, as well as means for detecting the presence and direction of unwanted noise. In this manner, appropriate sound waves can be generated and transmitted to the occupant to cancel the unwanted noise and thereby optimize the comfort of the occupant, i.e., the reception of the desired sound from the entertainment system **280**.

More particularly, the entertainment system **280** includes sound generating components such as speakers, the output of which can be controlled to enable particular occupants to each listen to a specific musical selection. As such, each occupant can listen to different music, or multiple occupants can listen to the same music while other occupant(s) listen to different music. Control of the speakers to direct sound waves at a particular occupant, i.e., at the ears of the particular occupant located in any of the ways discussed herein, can be enabled by any known manner in the art, for example, speakers having an adjustable position and/or orientation or speakers producing directable sound waves. In this manner, once the occupants are located, the speakers are controlled to direct the sound waves at the occupant, or even more specifically, at the head or ears of the occupants.

FIG. **5A** shows a schematic of a vehicle with four sound generating units **281,282,283,284** forming part of the entertainment system **280** of the vehicle which is coupled to the processor **101**. Sound generating unit **281** is located to provide sound to the driver. Sound generating unit **282** is located to provide sound for the front-seated passenger. Sound generating unit **283** is located to provide sound for the passenger in the rear seat behind the driver and sound generating unit **284** is located to provide sound for the passenger in the rear seat behind the front-seated passenger. A single sound-generating unit could be used to provide sound for multiple locations or multiple sound generating units could be used to provide sound for a single location.

Sound generating units **281,282,283,284** operate independently and are activated independently so that, for example, when the rear seat is empty, sound generating units **283,284** are not operated. This constitutes control of the entertainment system based on, e g., the presence, number and position of the occupants. Further, each sound-generating unit **281–284** can generate different sounds so as to customize the audio reception for each occupant.

Each sound generating units **281,282,283,284** may be constructed to utilize hypersonic sound to enable specific, desired sounds to be directed to each occupant independent of sound directed to another occupant. The construction of sound generating units utilizing hypersonic sound is described in, e.g., U.S. Pat. Nos. 5,885,129, 5,889,870 and 6,016,351 mentioned above and incorporated by reference herein. In general, in hypersonic sound, ultrasonic waves are generated by a pair of ultrasonic frequency generators and mix after generation to create new audio frequencies. By appropriate positioning, orientation and/or control of the ultrasonic frequency generators, the new audio frequencies will be created in an area encompassing the head of the occupant intended to receive the new audio frequencies. Control of the sound generating units **281–284** is accomplished automatically upon a determination by the monitoring system of at least the position of any occupants

Furthermore, multiple sound generating units or speakers can be provided for each sitting position and these sound generating units or speakers independently activated so that only those sound generating units or speakers which provide sound waves at the determined position of the ears of the occupant will be activated. In this case, there could be four speakers associated with each seat and only two speakers would be activated for, e.g., a small person whose ears are determined to be below the upper edge of the seat, whereas the other two would be activated for a large person whose ears are determined to be above the upper edge of the seat. All four could be activated for a medium size person. This type of control, i.e., control over which of a plurality of speakers are activated, would likely be most advantageous when the output direction of the speakers is fixed in position and provide sound waves only for a predetermined region of the passenger compartment.

When the entertainment system comprises speakers which generate actual audio frequencies, the speakers can be controlled to provide different outputs for the speakers based on the occupancy of the seats. For example, using the identification methods disclosed herein, the identity of the occupants can be determined in association with each seat-

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